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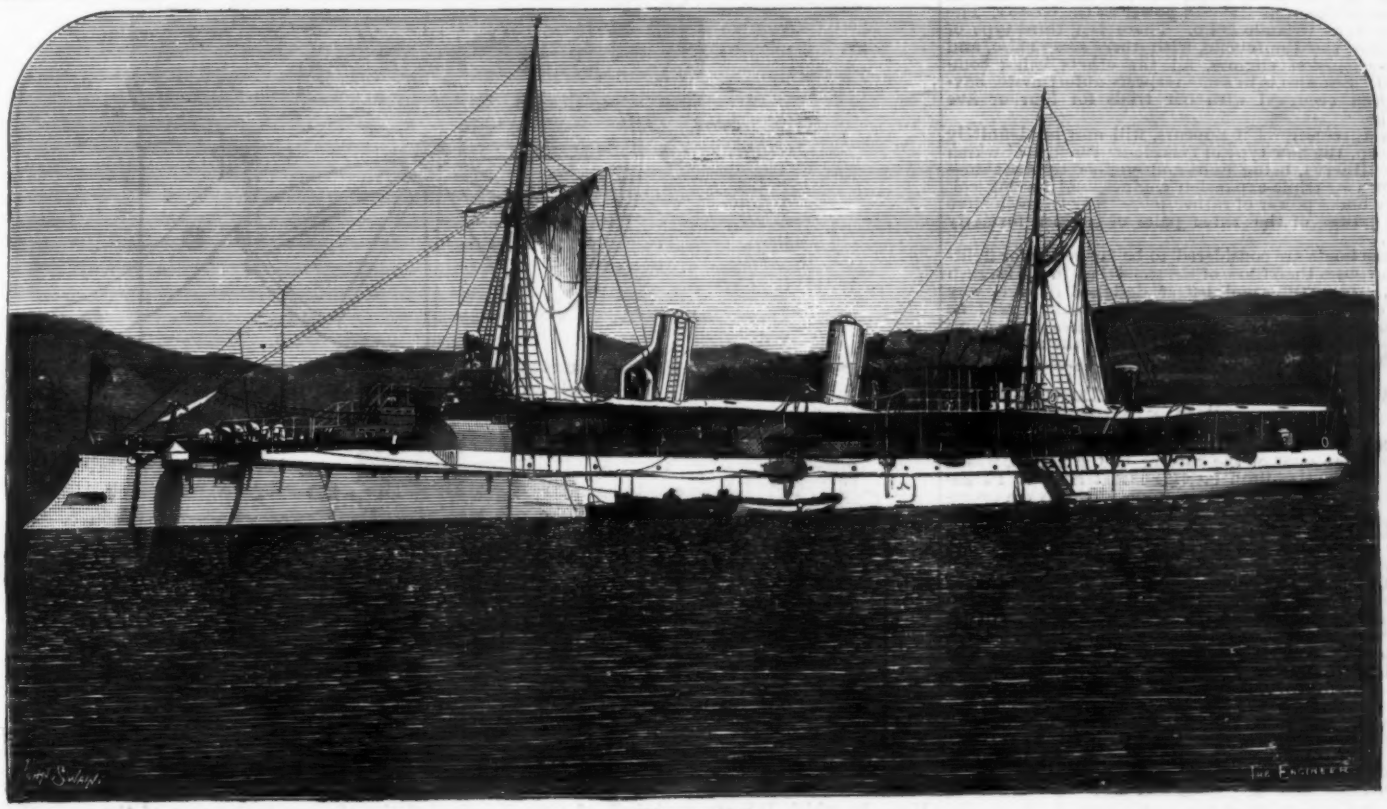
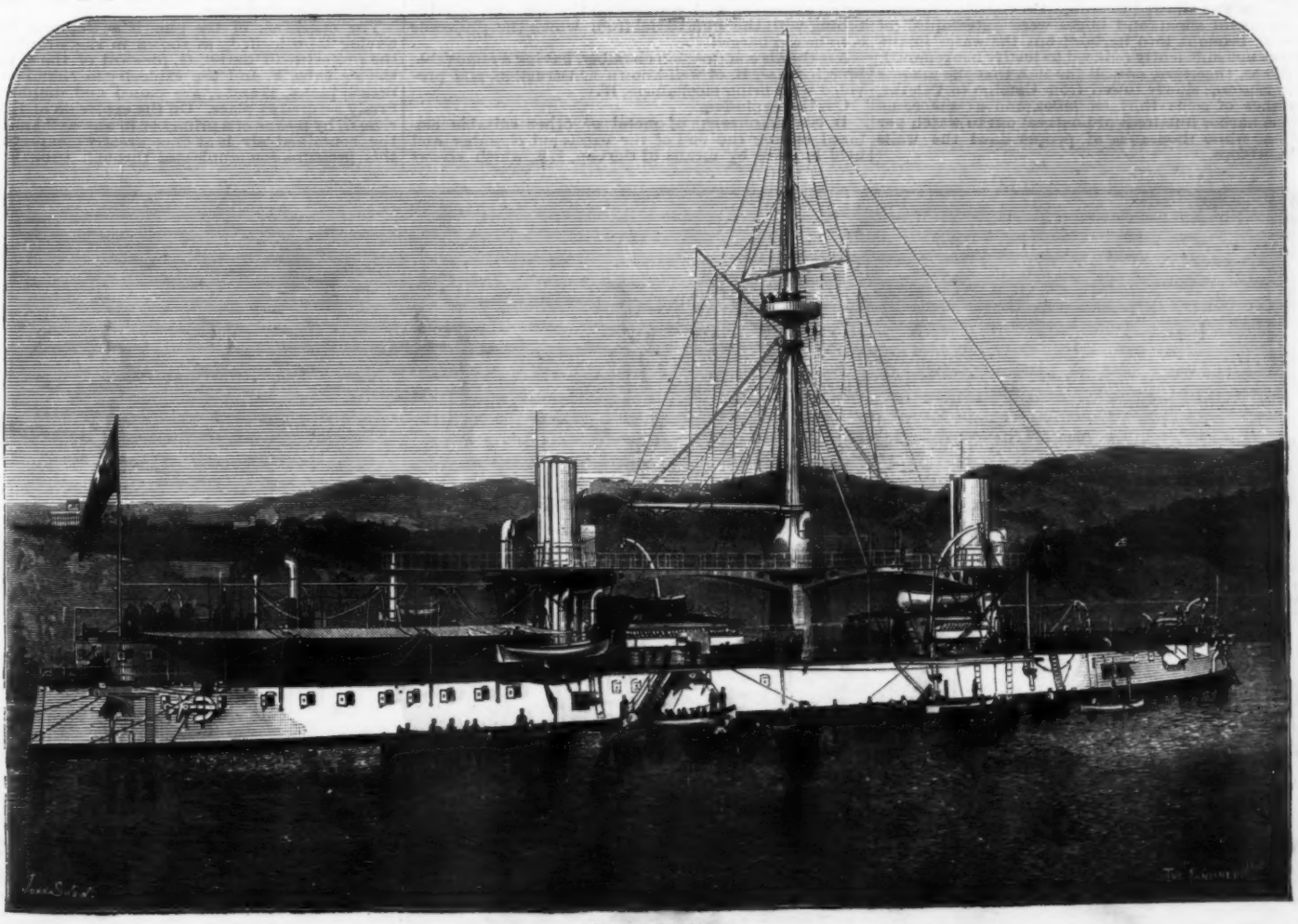


THE GOITO.



THE DUILIO.

ITALIAN WAR SHIPS.

ITALIAN WAR SHIPS.

WE give engravings of the Italian war ships Duilio and Goito, for which we are indebted to *The Engineer*. The Duilo is an iron vessel built at Castellamare, is a sister ship to the Dandolo, and is of 10,960 tons displacement. She is 339·7 ft. long, 64·5 ft. wide, and 26·8 ft. deep. She carries four 17·75 in. 100 ton muzzle-loading guns, and is of 7,710 indicated horse power.

The Goito belongs to the torpedo flotilla, and was constructed at the same place and launched in 1887. She is of 730 tons displacement, 229·7 ft. long, 25·8 ft. wide, and 9·5 ft. deep.

The Goito is one of the torpedo rams—we call them torpedo-boat catchers in England—with three screws. It will be remembered, however, that after exhaustive trials it was found that equally good results were obtained with the two screws at work as with the three. This resulted in the Saetta type, which is precisely similar to the Goito type, but has only two sets of engines of the same size and power as the Goito's. The Saetta is by Orlando & Co. There is a third type of this class, the Montebello, with three screws also, and triple-expansion engines, all the others being compound. She also is in some respects unfortunate, having been occupied with her trials for four or five months.

The three screws, it appears, will now be definitely given up, the new type of this class—the first of which is the Minerva, being built and engined by Ansaldo—having two triple-expansion engines, and having collective horse power of rather more than the collective horse power of the three pairs of engines formerly fitted.

These boats are considered to be far better for fighting purposes than those of the same class in the English navy, being stiffer and better designed in every way than our poor little Grasshoppers, which, it will be remembered, could not have their engines worked up to their full power, for fear of shaking them too much for their health.

RAISING OF THE BRITISH MAN-OF-WAR SULTAN.

A NAVAL officer sends to the London *Graphic* the following account of the raising of the Sultan, which Lord George Hamilton lately characterized in Parliament as "a distinct advance upon any salvage operations hitherto attempted, and attended with success."

"H. M. S. Sultan is once more a man-of-war, though sadly dilapidated, and as yet but half afloat, for, were the work of the pumps discontinued, she would soon fill and sink. After the grounding and subsequent sinking of the Sultan in March last, on the rocks in Comino Channel, near Malta, but little was done to her until the arrival of the Italian steamer Utile, belonging to the firm of Baghino & Co., of London and Messina, on June 1. From that date, however, active steps were taken. Many holes had to be stopped up by divers working with cement. Every aperture in the ship's side had to be plugged with wood or otherwise made watertight, and the combings on the upper deck were battened down or built up above the water as required.

"The first trial of pumps was made on the 27th of July, and a portion of the ship pumped dry on the 11th of August. She began to rise on the 18th instant, and on the evening of the 20th was afloat. But that evening, the wind rising, and water overcoming the pumps, she was allowed to sink. On the 24th instant she was again afloat, and hopes were entertained of her being brought into harbor; but the water in the ship was not sufficiently reduced to justify her removal, and it was, therefore, not till the 26th that she made a start. She was slowly towed from Comino to Valetta, a distance of some thirteen miles, and as she came near the harbor hundreds of boats set out to watch her progress, while thousands of people lined the walls and housetops.

"It was dark before the Sultan entered the harbor, and she was moored for the night in Bighi Bay, being taken alongside the dock yard on the morning of the 27th, and there she remained till sufficiently lightened to admit of her being taken into dock for repair."

Our engraving is from the *Illustrated London News*.

A NEW PNEUMATIC GUN.

THE Hotchkiss Ordnance Company (limited) have purchased the invention of Mr. Dana Dudley, of Lynn, Mass., by which it is expected shells of nitroglycerine can be safely fired by means of gunpowder.

The improved gun consists in providing a separate compartment, in which the air compression is produced by an explosive, and connecting the same by suitable tubing with the gun barrel from which the projectile is to be discharged.

A is the air compression chamber, having a removable breech piece, B, of well-known construction, and provided with firing mechanism, B'.

C is the explosive.

D is a diaphragm, of metal or other suitable material, closing the end of the explosion chamber and held in place by means of the cap, E E, which screws on to and partly over the end of the air compression chamber, A. This diaphragm, D, when thus secured in place, tightly closing the chamber, A, acts as a pressure safety valve, the resistance of the diaphragm providing one means for determining the degree of pressure that can be produced within the chamber. This required degree of resistance may be attained either by variation in the thickness of the diaphragm or in its material.

F F is an air tube, open at both ends, which connects the compression chamber, A, with the barrel, G,

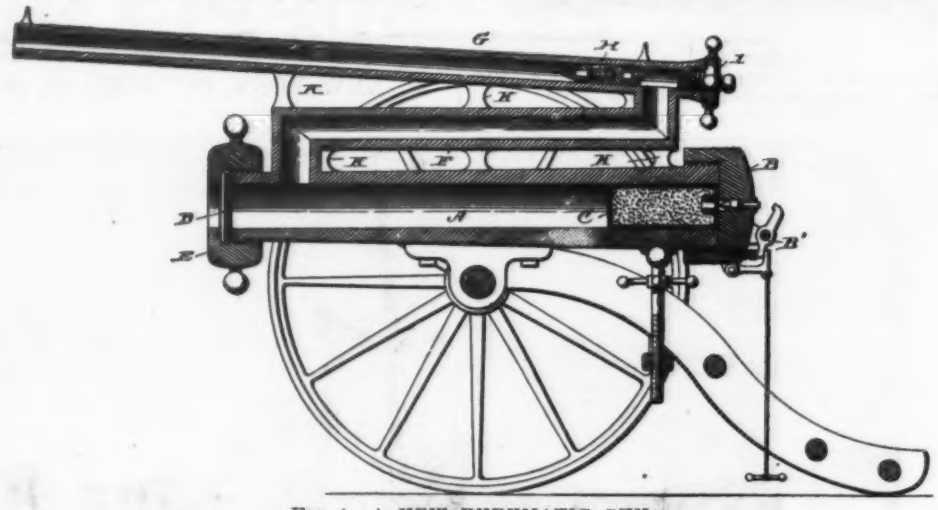


FIG. 1.—A NEW PNEUMATIC GUN.

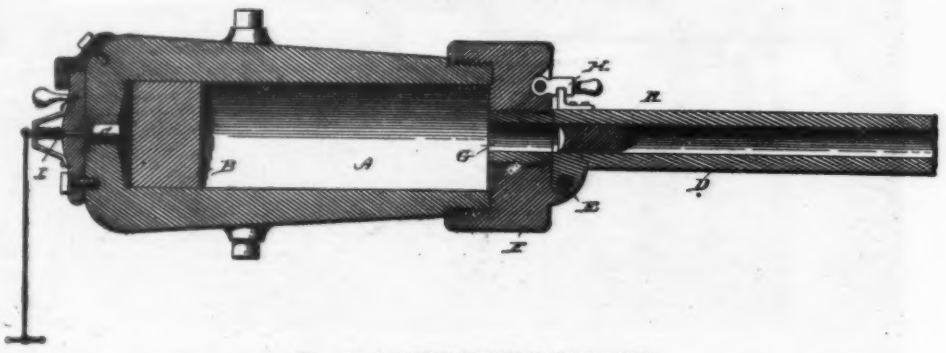
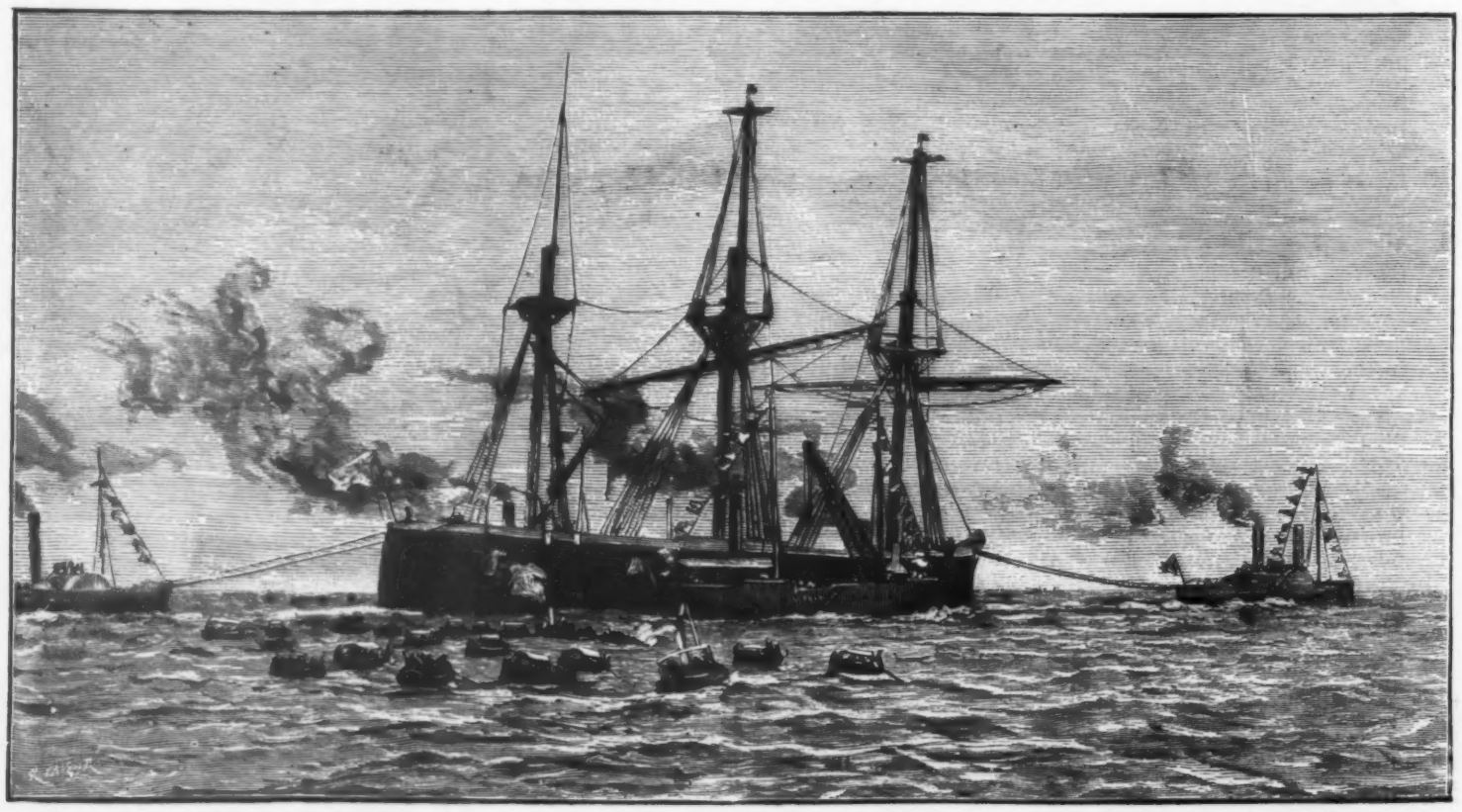


FIG. 2.—A NEW PNEUMATIC GUN.

of the air gun in the rear of the projectile, H, as shown.

I is the breech piece, removable for the purpose of introducing the projectile; and K K are braces to hold the parts together.

The operation of the gun is as follows: The gun having been loaded, as shown in the drawing, with the projectile in barrel, G, forward of the entrance of the air tube, F, and the explosive in chamber, A, the breech pieces, B and I, are closed and diaphragm, D, firmly secured in place. On the explosion of the explosive, C, by means of a primer or in any well known way, the contained air is at once greatly compressed, and this pressure communicated through tube, F, to the



RECOVERY OF H. M. S. SULTAN, SUNK OFF THE ISLAND OF MALTA.

rear of the projectile in barrel, G, discharging the gun.

A gun of the following dimensions will give good results, in which the diameter of the bore proper (barrel, G) is one and one-half inches, length eighty-four inches; diameter of air tube (tube F) is two inches, length forty inches; diameter of air compression chamber, A, is three inches, length thirty-eight inches; weight of projectile is two pounds, of powder charge eight ounces, and the resistance of plate, D, to blowing out forty-five pounds per square inch.

Among numerous advantages are the great simplicity and consequent cheapness of construction, the facility with which the air pressure is produced, and the absence of any fouling of the gun barrel due to the smoke and unburned powder.

It is evident the explosive charge and the gun barrel, G, remaining unchanged, the pressure in the latter may be regulated by varying the size of chamber, A. It is also evident the chamber may be of any convenient shape, provided always that it has means for the introduction of the explosive and for connecting it with the barrel containing the projectile.

Fig. 2 shows another form of the invention.

A is the air-compressing chamber, having the sliding piston, B, in the rear of which the explosive, C (here represented as a blank cartridge), is inserted.

D is the barrel pivoted at E to the headpiece, F, which closes the chamber, A, and which is provided with the duct or passage, G, for the compressed air.

H is a lock for retaining barrel, D, in position after loading.

I is the mechanism, of well-known construction, for loading and firing the explosive, and K is a projectile.

The gun may be provided with trunnions, as shown.

The operation of the gun is as follows: Piston, B, having been pushed to the rear end of chamber, A, as shown in the drawing, the explosive, C, and projectile, K, charged as shown, and barrel, D, locked in position, the explosive, C, is then discharged, driving piston, B, before it to the other extremity of the chamber, A. The air compressed in front of piston, B, is conducted to the rear of the projectile in barrel, D, where its expansion expels the projectile, C, from the barrel.

THE GUN.*

WE now come to the hoops. These are of puddled or forged cast steel. They have likewise been made of cast steel without flaws, but as the results have not been very satisfactory, it appears that such manufacture has had to be abandoned. Hoops of puddled steel, which, in recent years, have been employed only on land artillery, have likewise been discarded for guns of all calibers, and have been replaced with forged cast steel hoops.

Puddled steel hoops, especially for large calibers, present great difficulties in the way of manufacture which involve grave inconveniences, and which have led to the use of forged and tempered cast steel.

For the manufacture of hoops, an ingot is taken and forged in octagonal section and divided while hot into as many portions as there are hoops to be made. The final sectioning of these pieces is operated while they are cold, in order that the central fracture may be judged of. Each block is afterward heated, and the angles of the octagon are rounded off under the power hammer. Then the block is hammered flat in order to reduce its thickness, and is perforated with a drill while cold, and the work is finished by increasing its diameter on the anvil.

The hoop is afterward reheated, and finished in the rolling mill or under the power hammer, according to its dimensions.

For hoops with trunnions, the ingot having been forged, one of the trunnions and the body of the hoop is rough-forged, and then separated from the ingot, and the rough-forging of the second trunnion is proceeded with. Then, in the body of the cold hoop, a slit about two inches in width is cut by means of a mortising machine (Fig. 5). The piece is afterward heated, and then this aperture is enlarged under the power hammer and brought progressively to a circular form by means of appropriate mandrels. Finally, the definite dimensions are given to the rough-forged hoop. This process of manufacture has been patented by Messrs. Schneider & Co. The hoops are annealed after forging, then tempered in water or oil, and finally undergo another annealing after being tempered.

With hoops of forged cast steel, tractive tests are made before tempering, in order to allow the quality of the metal and the height of temper to give it to be judged of. After this, specimens to be submitted to traction and impact are taken from the rough-turned pieces. In addition to such tests, each hoop individually undergoes a mandreling test that permits of ascertaining what its elastic qualities are.

When the tube and the hoops that are to compose a gun have been found to be of a good quality and free from defects capable of interfering with their use, the finishing up is begun.

A beginning is made by finishing the interior, the faces, the body, and the collars or hoops of the first row, and then the definite external dimensions, regulated by the internal diameters of the forementioned pieces, are given to the tube. Afterward these pieces, which are put upon the tube cold, are heated, and then are chilled in order to fix them by shrinkage. When all the hooping of the first row is in place, it is submitted to the action of a lathe in order to remove the slight projections that may exist from the fact of the differences in thickness; and the external dimensions are regulated by the size of the internal diameter of

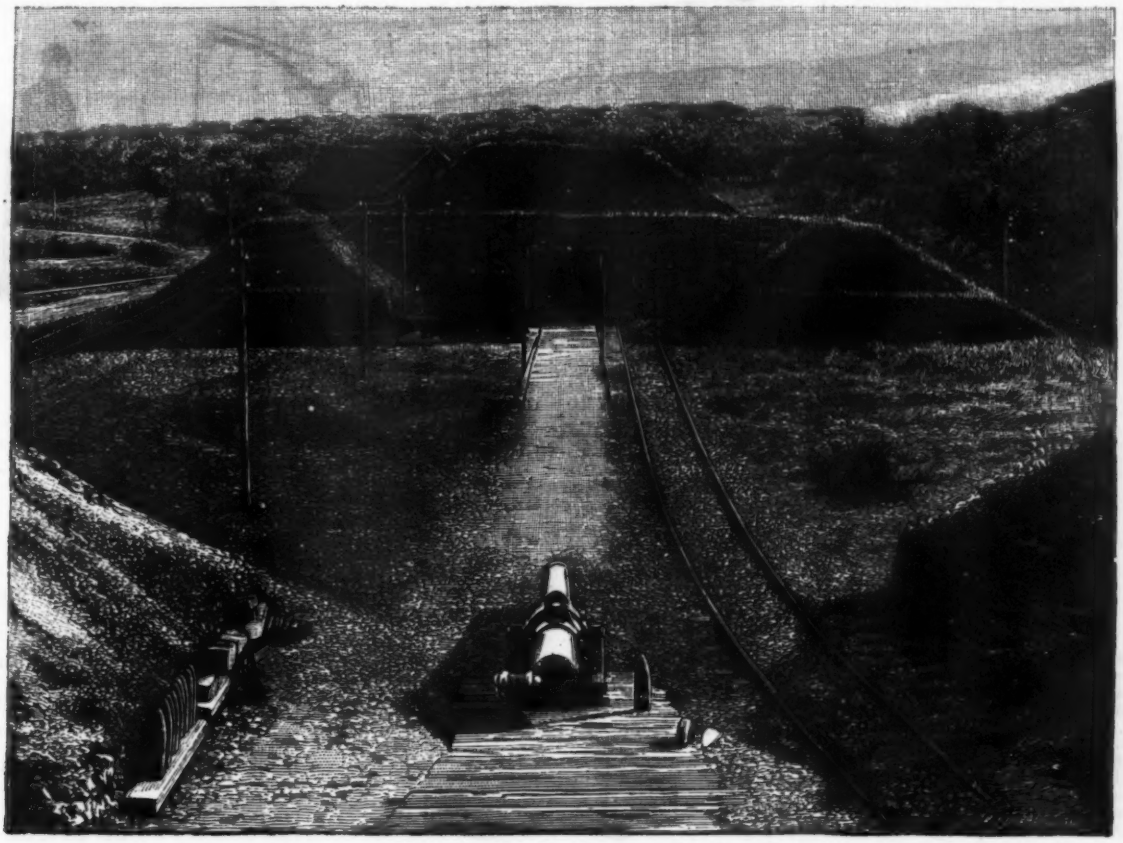


FIG. 1.—THE VILLEDIEU PROVING GROUNDS.

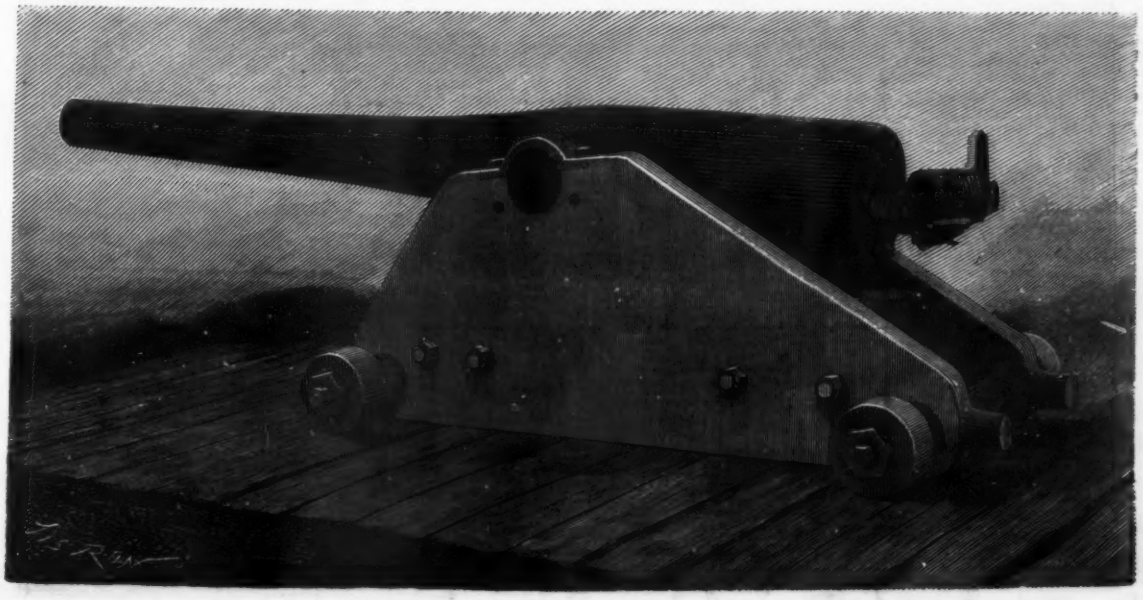


FIG. 2.—12½ INCH HONTORIA GUN OF THE ROYAL SPANISH NAVY.

* Concluded from SUPPLEMENT, No. 718, p. 11464.

the hoops of the second row. These latter and the trunnion hoops are put in place in the same way that those of the first are.

The gun is afterward bored out, and finished externally in a lathe, and then the chamber is bored out and the tube is rifled.

When these operations are finished, the breech is threaded and the threads are divided into sections. Then are definitely finished the pieces that constitute the breech-closing mechanism, and the adjusting of which is done in part during the putting together of the gun.

making the parts and putting them together are placed in an excellent situation for the manufacture of ordnance. On the one hand, they do not have to compete with others, which is important—and have every liberty of movement; on the other hand, in case of imperfect equipments, they cannot intrench themselves behind responsibilities that rest only in part upon those which do not produce the elements. They are responsible for the guns that they deliver ready to be put in service, and if these are defective, the error committed is wholly chargeable to the makers.

At Creusot, as we have already said, not only are

maneuvered by manual power, while the bridges in the two other compartments are mechanical.

Under each rolling bridge there runs throughout the length of the building a railway that permits of a car being hauled by a locomotive to any point of the hall.

The grounds around the works will permit of doubling the latter's length whenever it is desired, and the tracks of the rolling bridges have been constructed for the reception of other similar bridges, so as to make it possible to lift, for example, a 120 ton gun by the coupling of two 60 ton bridges.

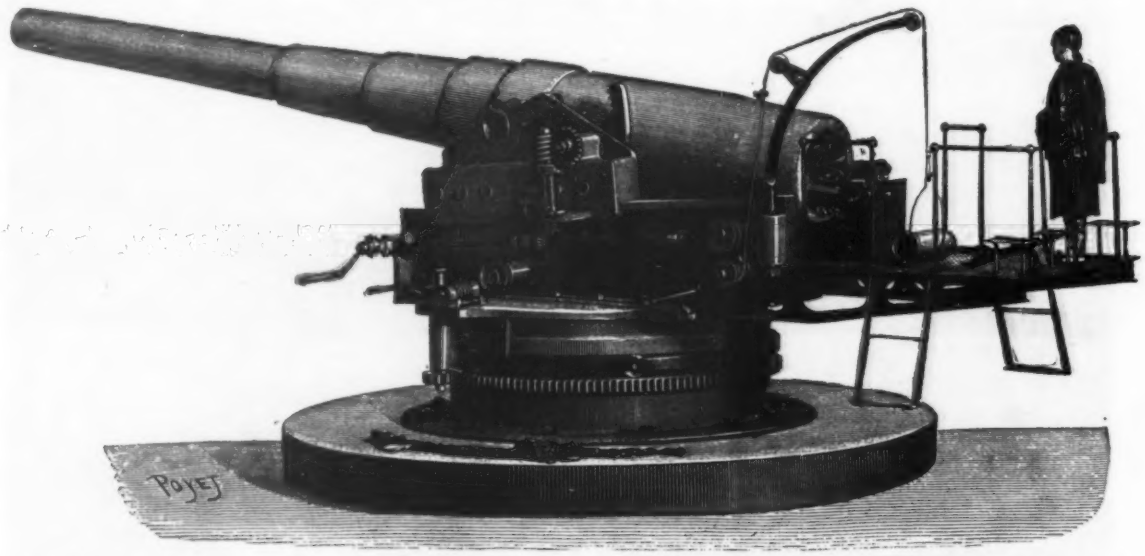


FIG. 3.—9¼ INCH GUN, MOUNTED ON A CENTRAL PIVOT CARRIAGE, PROVIDED WITH A HYDRAULIC BRAKE; MANUFACTURED FOR THE CHINESE GOVERNMENT.

We must not pass over in silence the numerous verifications of the dimensions made, during the process of finishing, with an apparatus called a "movable star." This apparatus, that permits of taking the dimensions to $\frac{1}{1000}$ of an inch, is used after every passage of the drill, and after rifling, in order to verify the depths of the grooves, and, finally, in the verification of the internal diameter of the hoops, data which it is necessary to have with mathematical precision for the important determination of the closeness of the fit.

Up to the present, the use of so perfect a measuring instrument has been made scarcely anywhere except in France, and the construction of guns in England is far from being done with such precision.

In the above definite state, the gun has afterward merely to be mounted upon its carriage in order to be put in service after the prescribed firing tests.

The complete manufacture, inclusive of the finishing up, of a 3½ inch gun, takes about six months, while

the parts of guns finished, but there is a complete equipment of tools embraced in a vast establishment, the construction of which is relatively recent, and which, not including its dependencies, occupies an area of 40,300 square feet. It comprises three compart-

FIG. 5.

ments—a central one 50 feet in width and two lateral ones each 32 feet in width and 25 feet in height.

The machine tools, on account of the means of lifting, are grouped according to the weight of the pieces that they are designed to work. In the central compartment are found, along with a 60 ton rolling bridge, the machines designed to receive guns up to 120 tons in weight and 50 feet in length. In one of the lateral compartments, provided with a 15 ton rolling bridge, are placed the machines designed to work guns of medium size; and, finally in the other compartment, are found all the small machine tools capable of working the breech mechanisms, the accessories, torpedo tubes, etc. This compartment is provided with rolling bridges

A suitable space is reserved in the central hall for the mounting of guns, carriages and armor-plated turrets, alongside of the machine tools that take part in this sort of work.

The motive power of the works is furnished by a powerful engine that receives its steam from three tubular boilers with internal furnace. The works are lighted through large windows in the four sides and through two glazed galleries situated in the interval between the wall plates of the large and small trusses. All parts of the works are lighted at night by means of arc and incandescent lamps supplied by two dynamos and a special motor.

Water under pressure is supplied at every point where it is needed, especially for the tempering of tools and the putting on of hoops. The gas designed for the lighting of the yards is led likewise to the plant, for supplying the blow-pipes that are used for heating certain tools. The tool works, which occupy an area of

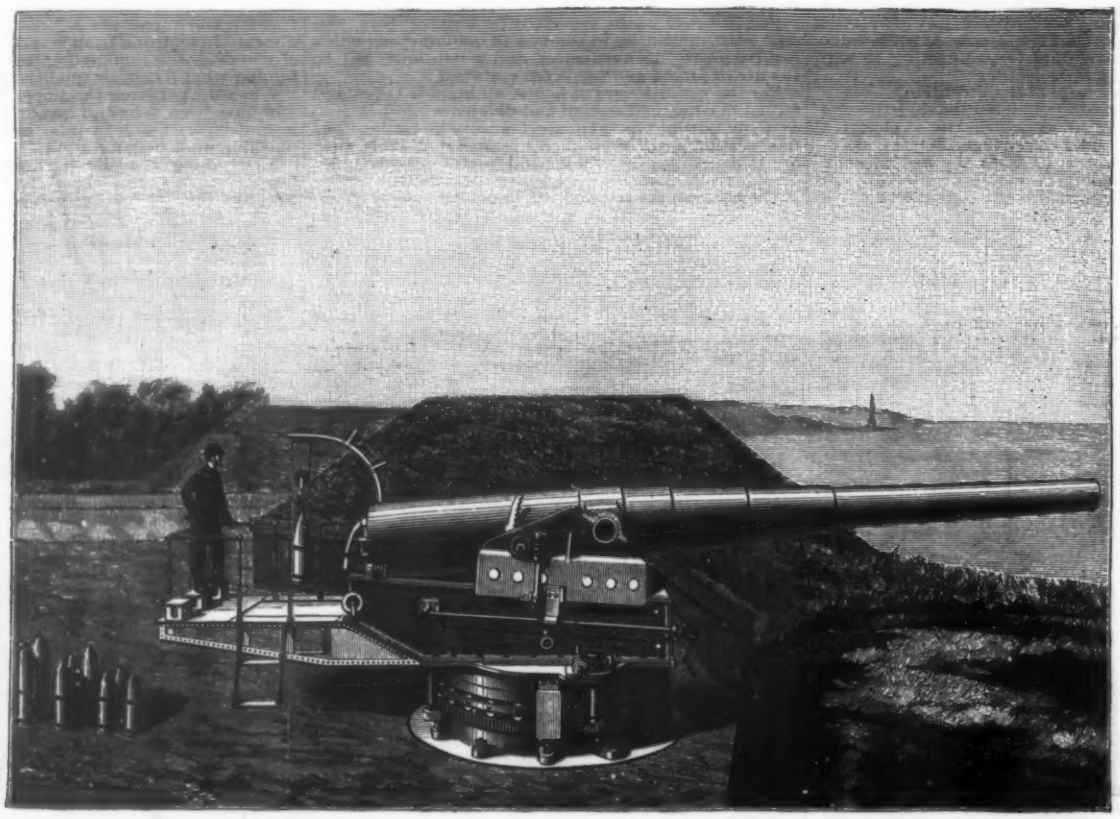


FIG. 4.—9¼ INCH GUN, MOUNTED UPON A HYDRAULIC, CENTRAL PIVOT COAST CARRIAGE.

that of a 14½ or 16¼ inch necessitates about two years.

The production of the parts, as may be seen, consists of a series of operations that may be performed by well-equipped forges; but if it be desired to construct finished guns, it requires a special organization, so much the more extensive in proportion as the guns are of larger caliber.

It is evident that such gun works as are capable of

7,300 square feet, are provided with the most improved machine tools for the manufacture of the most varied tools—a group of forges, a power hammer, and a special installation for the heating and tempering of tools. A portable furnace, serving for the putting on of hoops, is installed in the works, under the 15 ton rolling bridge. Its dimensions permit of heating the trunnion hoops of guns of the largest caliber.

The workmen have at their disposal every instru-

ment for measurement and verification in use in workshops of high precision, such as the standard meter with vernier to the 1 100th, tempered mandrels, movable stars, etc.

The ordnance works are connected by rail with the Villedieu proving grounds (Fig. 1), where armor plates and guns ars tested. These grounds are provided with all the apparatus necessary for experiments in firing.

As stated above, Creusot has delivered to the French navy the elements of 319 steel guns and of 167 cast iron

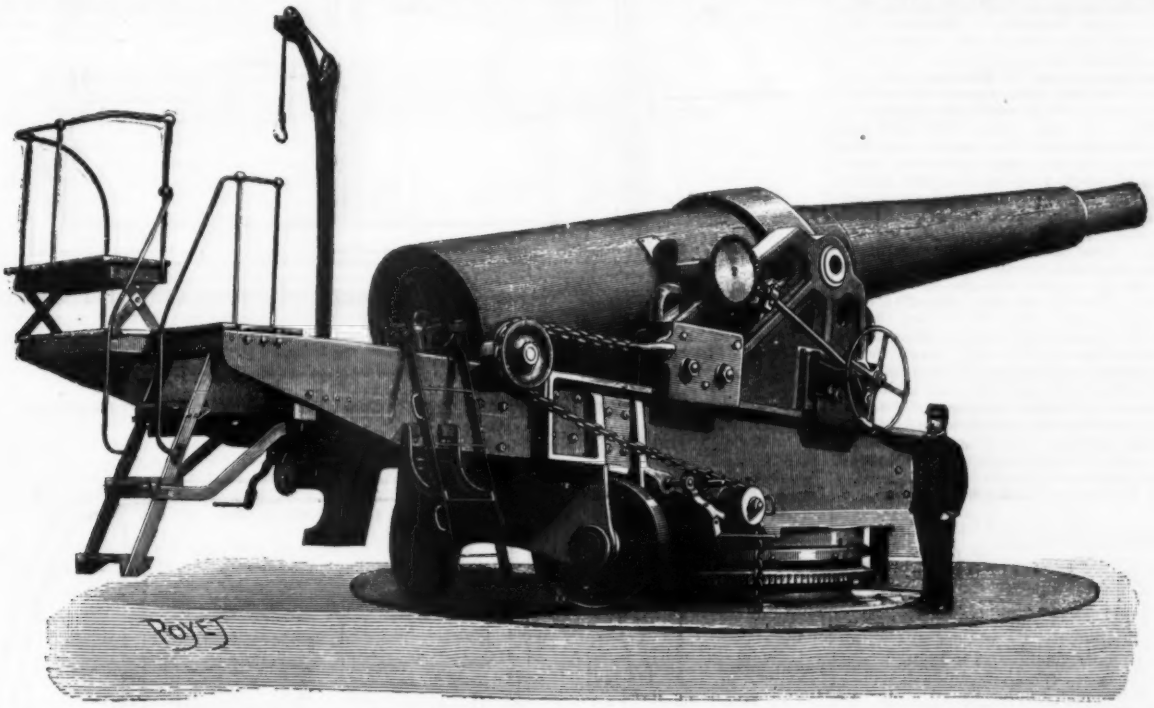


FIG. 6.—COAST CARRIAGE, WITH HYDRAULIC BRAKE, FOR A 12½ INCH GUN; CONSTRUCTED FOR THE FRENCH NAVY.

ones; but it must be added that, as regards elements, it has likewise made deliveries to foreign navies.

During the Franco-German war, the government of the national defense addressed itself to the large manufacturers for artillery, and, thanks to the energy and patriotism of all, we were enabled to bring upon the field of battle a respectable artillery. At this period, Creusot delivered in a completely finished state, to our army, 41 batteries of 250 pieces.

Later on, after the peace, when we reconstructed our armament, Creusot had to make some hundreds of completely finished pieces for our army, and, among others, guns of 8⅕ and 9¼ inch and mortars of 8⅕ and 10½ inch caliber. In 1881, General Hontoria ordered of it 24 pieces of ordnance for Spain (Fig. 2). At present, the works are finishing for the Chinese government four steel 9¼ inch guns (Figs. 3 and 4), with central pivot carriages, and designed for the defense of the coasts of the Celestial empire, and also two 25¼ inch mountain guns with carriages. These pieces are designed after patterns belonging to Creusot, and which differ in some points from the patterns of the French navy.

We shall have finished this nomenclature when we shall have said that these works have delivered the rough-finished elements of more than 4,000 guns of French land artillery, and that the number of pieces of ordnance in the construction of which they have cooperated amounted, in the month of May last, to 5,551.

If to this we add the elements of 6,735 Hotchkiss guns, 2,225 carriages for land and naval guns of all calibers, 330 carriages, forges and wagons for campaign batteries, large quantities of supplies for projectiles, and, finally, a multitude of those pieces that arsenals employ for the manufacture of war *materiel*, we shall have an idea of the co-operation that the Creusot works have given and can again give in the national defenses.—*Le Genie Civil.*

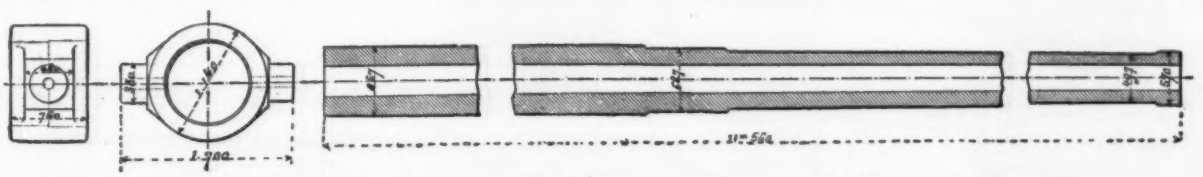


FIG. 7.—TRUNNION HOOPS AND ROUGH-TURNED AND BORED TUBE FOR A 12½ INCH GUN 36 CALIBERS IN LENGTH.

FIG. 8.—(1) TUBE FOR A 12½ INCH HONTORIA GUN. (2) BODY OF A 2½ INCH GUN OF THE FRENCH NAVY.

BALDWIN LOCOMOTIVE No. 10,000.

WE take some particulars of the ten-thousandth locomotive built by the Baldwin Locomotive Works. Very appropriately this engine is one of the heaviest consolidations. It belongs to the class weighing 75 tons without the tender, with a weight of 135,000 lb. on the drivers. It is designated as class 10-38-E 32.

This engine is one of several of the same class built for the Northern Pacific, where they have been very successfully used on the heavy grades and sharp curves of the mountain sections. A recent report of the performance of one of them states that it has hauled 20 loaded cars, weighing about 600 tons, on grades of 116 ft. and curves of 10 degrees. The total load, including engine and tender, was probably 712½ tons.

On such heavy grades the resistance due to unknown factors is a small percentage of the total resistance. In this particular case the resistance due to the grade alone is much larger than all the other resistances. Therefore the estimates based upon the conditions are of interest and, perhaps, of value. The grade is 116 ft. per mile, or about 2·2 per cent. This alone would cause a train resistance of 30,400 lb. A fair estimate of the frictional resistance is 6 lb. per ton of total load. This increases the resistance by 4,300 lb. It will be seen how small is the frictional or uncertain portion of the total resistance when the grades are heavy A certain amount of resistance should be added to these because of the 10-degree curve and the 20-car train, and a fair estimate of the total might be safely stated at 37,000 lb. This calls for an adhesion of the driving wheels to the track equal to 548 lb. for each ton of weight thereon, and an average pressure on each 22 in. piston of about 148 lb., including an allowance of 8 per cent. for frictional resistance of the locomotive itself. A drawbar tension of nearly 33,000 lb. is enormous, and directly measures the demands made by heavy freight service at the present time, and following in the wake of such demands comes the necessity for an increase of grate and heating surface nearly in proportion.

This locomotive, with about 36 sq. ft. of grate surface and 2,393 sq. ft. of heating surface, of which 172 sq. ft. is firebox surface, bears out the proportions common to the better class of smaller locomotives.

This engine gives evidence, better perhaps than almost any other or previous design, of the change in the opinions of railroad engineers regarding the maximum weight per wheel permissible for locomotive engines.

Although this locomotive is of the consolidation type, yet it is not strictly the result of the growth of that type, and can hardly be said to represent the development of the original plan of the consolidation engine. It is really a modification of the decapod plan, and the name "octapod" has been suggested therefor by the builders.

The details of the engine resemble the consolidation type, but the work for which the locomotive is intended is that for which the decapod type was originally built. When the decapod was first conceived the maximum weight per single driver permissible was such that it required ten pairs of drivers to carry sufficient weight to do the work required. Since that time the increase in the allowable weight per single driver has been so much that one pair of drivers has been dropped, the result being the design illustrated by No. 10,000

This locomotive weighs on eight drivers 135,000 lb., or 16,870 lb. per driver. If the weight carried on four drivers on some fast passenger locomotives, that is, 68,000 to 74,000 lb., is not detrimental to the track, and if such heavy weights per wheel are, as it would seem, growing in favor, then, except for the effect of the massing of great weights on bridges, there is little reason why such locomotives as No. 10,000, running at slower speeds, should not carry 136,000 to 148,000 lb. on eight wheels, and perhaps even more if the few express locomotives now running with 19,000 lb. per wheel are not found to be destructive to the permanent way.

Regarding the massing of heavy weights upon bridges, there are several reasons which it is needless to mention here why a slow-running freight locomotive even with a large weight per running foot would not damage or strain a given bridge as much as high-speed locomotive of less weight per foot of wheel base.

The type of locomotive represented by No. 10,000 is intermediate between the average consolidation and the decapod, and the builders feel that, owing to the recent great increase in the maximum weight per wheel, the decapod is a little ahead of the times, believing, as they do, and as nearly every one else seems to, that the same weight carried on eight wheels will furnish as much adhesion as if carried upon ten wheels, and perhaps more traction on the drawbar—which is a measure of the useful work—in proportion to the power generated in the cylinder, because of the additional friction of the fifth pair of rods and wheels.

The Philadelphia and Reading, when considering the adoption of a heavy class of freight engines, hesitated between the decapod and this class of consolidations, until the experience with the heavy eight-wheel express locomotives showed that the increased weight per driver was admissible on their permanent way.

There is one point in favor of the consolidation which will, as well as the increase in maximum weight per driver, put off the day when the decapod will be the more favored type. It is the greater flexibility of the wheel base of the consolidation. This is a point of no small advantage on the mountain roads, where these types of engines are most needed.

It may be interesting to give here the origin of the term "consolidation" as applied to locomotives. It had its birth in the consolidation of the Lehigh Valley and the Mahanoy Railroads about the year 1866. At that time a locomotive with 10 wheels, 8 of which were drivers, was building at the Baldwin Works for the Mahanoy Railroad, and as this locomotive was to become the property of the consolidated roads, it was thought *apropos* to christen it the "Consolidation," it being the fashion in those days in the Middle States, as it is now in some parts of New England, to give to locomotives names suggestive of either great size, power or speed. It was thus that the first consolidation appeared as a 20 in. × 24 in. locomotive, weighing 90,000 lb., while to-day the consolidation is generally built with the same cylinders, but weighing about 130,000

lb. The first of the type had a wagon top boiler, 50 inches in diameter, with a firebox down between the frames, and, therefore, of necessarily small dimensions. Now the same type has 56 to 60 in. straight boilers, with the firebox on top of the frames, and much greater dimensions are thereby permitted.

It is suggestive that the weight upon the drivers of the consolidation type has been increased about 50 per cent., and, therefore, its working capacity, and yet the cylinders remain the same, while the steam pressure has been increased but about 15 per cent. It indicates what has before been discussed in the *Railroad Gazette*, that there has been a large increase in the work demanded from locomotive cylinders of late years without a corresponding increase in dimensions.

That this has been productive of greater economy there can be no doubt, but we cannot go much further without turning the corner and meeting loss instead of increased gain. When it was discovered that the heavier locomotives worked with even better economy than the lighter ones with the same cylinder, there was a general feeling of relief, and the acquired knowledge was most welcome, because it solved the problem of the production of more powerful motors without material changes in the working parts.

About the time that these changes were being made the stationary steam engineer discovered that it was not economical to use the early cut-offs in a steam cylinder, and that, at a 22 to 25 per cent. cut-off, steam engines were more economical than at 10 and 15 per cent. cut-off. This knowledge gave to the locomotive builder increased confidence in the step taken in increasing the demand from locomotives without increasing the cylinder capacity, thus necessitating a longer cut-off. The two most probable reasons for the increased economy of the heavier engines lies in the nearer approach in the average working to the most economical cut-off, and the reduction of the loss of steam caused by the slipping of the drivers.

The following are the general dimensions:

Gauge	4 ft. 8½ in.
Actual weight in working order, exclusive of tender	150,000 lb.
Actual weight on driving wheels	135,000 lb.
Estimated weight of tender, including coal and water	75,000 lb.
Estimated weight of locomotive and tender, in working order	225,000 lb.
Cylinders	22 × 28 in.
Ports—Length	16 in.
" Steam port width	1¼ in.
" Exhaust port width	3 in.
Bridge	1¼ in.
Center to center of cylinders	86 in.
" valves	79 in.
Diameter of piston rods	4 in.
Throttle—Poppet balance, diameter	7⅛ in.
Dry pipe diameter	7⅛ in.
Steam pipe diameter, each	6 in.
Lap of valves	¾ in.
Valve travel	5¾ in.
" lead	1-10 in.
Eccentric travel	5 in.
" diameter	16 in.
Length of crosshead	20 in.
Driving wheels, four pairs coupled, diameter	50 in.
Engine truck wheels diameter	30 in.
Main pin diameter	6 in.
" length	6 in.
Tire flange width	5⅛ in.
" thickness	3 in.
Tire, plain, width	6½ in.
" " thickness	3 in.
Driving wheel seats, diameter	8⅛ in.
" " length	7 in.
" journals, diameter	8½ in.
" " length	9 in.
Driving axle, diameter in middle	8⅝ in.
Engine truck wheel seat, diameter	4⅞ in.
" journal, diameter	7 in.
" " length	9 in.
" axle, diameter in middle	4¾ in.
Total wheel base	22 ft. 3 in.
Driving wheel base	14 ft.
Total wheel base of engine and tender	49 ft.
From center of truck to first drivers	99 in.
" " of first drivers to second drivers	58 in.
From center of second drivers to third driver	52 in.
From center of third drivers to fourth drivers	58 in.
Center to center frames	46 in.
Boiler of steel, ⅝ in. thick	72 in. diam.
Length of barrel	19 ft. 7 in.
Diameter of barrel	72 in.
Thickness of tube plate	½ in.
Rivets, diameter	1 in.
" pitch	3⅛ in.
" style steam	Butt.
Height of center line of boiler above rails	7 ft. 8 in.
Fire box, length	10 ft. 1 in.
" width inside	425⅛ in.
" depth	62¾ × 59½ in.
" material crown thickness	⅜ in.
" sides and back	5-16 in.
" tube	½ in.
" stay bolts, diameter	⅞ in.
" " center to center	4⅛ in.
Tubes, 271 in number, 2¼ in. diam.	13 ft. 6 in. long.
Thickness	No. 12 B. W. G.
Smoke stack, diameter	18 in.
Height from rail to top	14 ft. 6 in.
Heating surface of firebox	172 sq. ft.
" " tubes	2,121 sq. ft.
Total heating surface	2 393 sq. ft.
Tank capacity	3 6 0 gal.
Driver brake	Eames equalized.

—*Railroad Gazette.*

Seamless boiler tubes are now made from solid ingots of metal by a process that twists and stretches the fibers, and is said to make a tube much stronger than the ordinary ones.

ELEVATING PLATFORM FERRY STEAMER.

We illustrate herewith the elevating platform ferry steamer which Messrs. William Simons & Co., Renfrew, are constructing for the Clyde Navigation Trustees.

It is to be employed at Finnieston, Glasgow Harbor, in connection with the cross-river service.

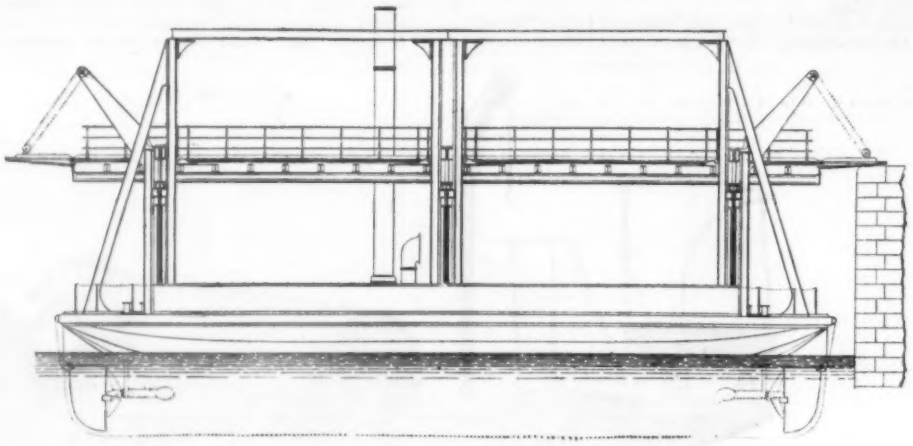


Fig. 1.—SIDE ELEVATION OF THE FERRY STEAMER AND ELEVATING PLATFORM

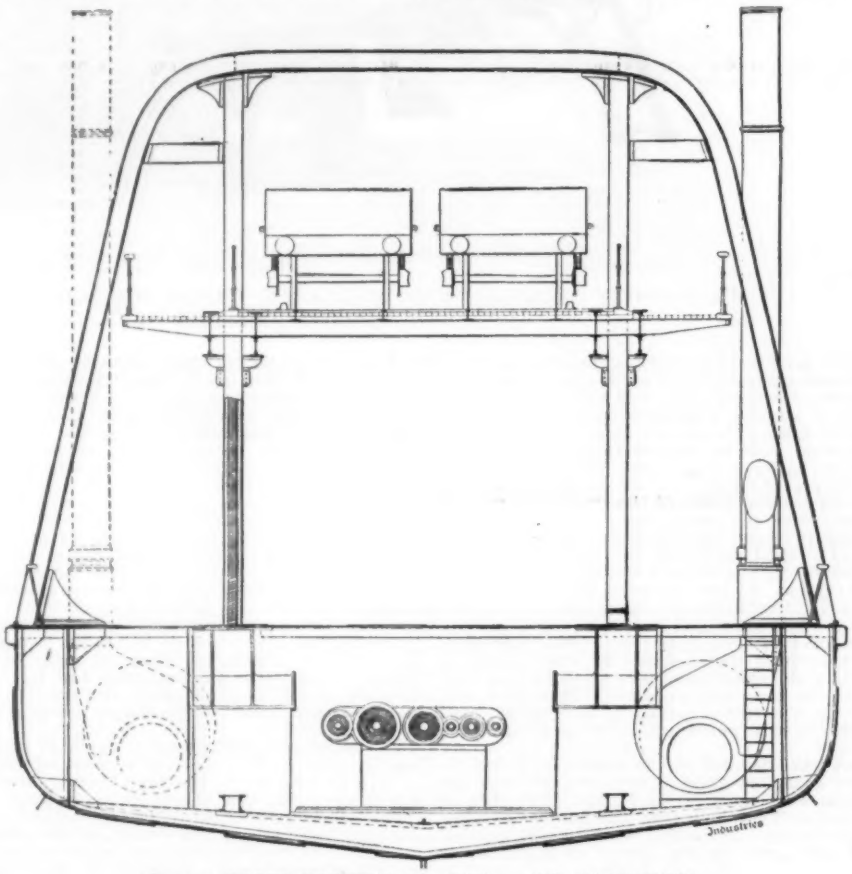


Fig. 2.—CROSS SECTION OF HULL AND PLATFORM.

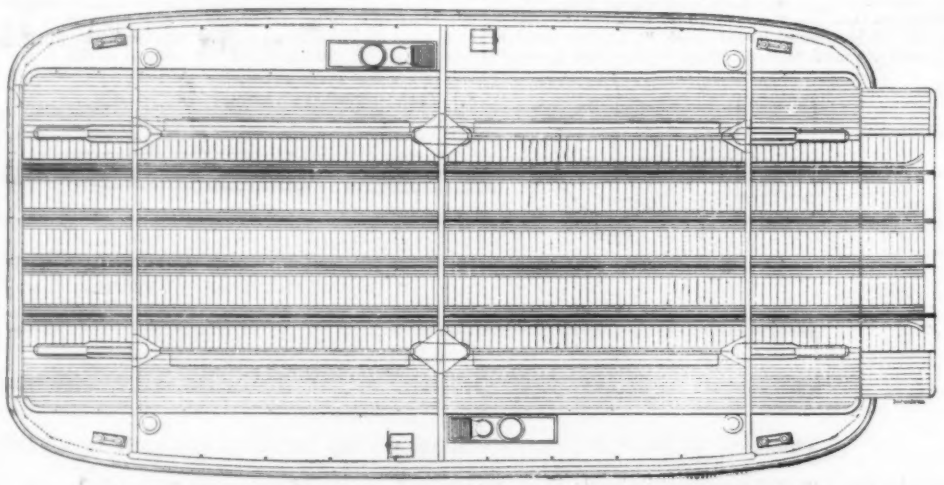


Fig 3.—GENERAL PLAN OF DECK AND ELEVATING PLATFORM.

ELEVATING PLATFORM FERRY STEAMER.

This boat is being built under the superintendence of Mr. James Deas, engineer to the trustees of the Clyde Navigation, and it is expected that it will solve the problem of cross-river communication in the lower reaches of Glasgow Harbor.

Its distinctive feature is an elevating deck (besides the ordinary deck), which extends the whole length of the boat, and occupies about half its width. The following are the principal dimensions of the vessel:

Length, 80 ft.; breadth, 43 ft.; depth amidships, 12 ft. The hull is constructed of steel, and the deck underneath the elevating platform of iron, and at the sides beyond the platform of thick pitch pine planking.

In case of collision, the hull is divided into thirteen watertight compartments by longitudinal and transverse bulkheads. Under the main deck ample and comfortable accommodation is provided for the crew and engineers, and the necessary sleeping berths, tables, seats, etc., will be fitted up. A rudder will be fitted at each end of the vessel, and the steering wheels will be placed amidships, as shown on the deck plan (Fig. 3). Each rudder will have a movable lock bar to keep it in position when the opposite rudder is being used. Steam will be used for steering purposes. Suit-

able mooring bitts will be provided at each end for securing the vessel when at the quay

The elevating columns or uprights for supporting the platform are six in number, and will be of box form of girder work of ample section, and strongly bracketed to the deck. These uprights are bound together by stays running fore and aft, and on the top by girder bars.

The elevating platform, which runs fore and aft, is 78 ft. long, and has an extreme breadth of 32 ft., of which 19 ft. in width is set apart for vehicles, and a width for passengers on each side of about 6 ft.

This platform will be formed of two strong longitudinal steel girders of I section, for each line of columns, and of ample strength to carry the maximum load with safety. On these girders will rest transverse girders of similar form placed fully 3 ft. apart, and carried across the platform in one length. Intercostal girders will be placed above each of the longitudinal girders. The part of the platform for vehicular traffic will have a thick covering of pitch pine, clad diagonally with elm planking, and on each side of this platform will be laid two lines of steel rails adapted for railway carriages and wagons, and two rows of flat iron will be fitted in each vehicular space for cart wheels.

For embarking and landing the traffic, on each end of the vessel is fitted a suitable gangway, shod with strong plate iron. It will be raised and lowered by means of chain pulleys and handwheels placed conveniently amidships. The gangways will have lines of rails corresponding to those on the platform. The rise of the platform or deck will be fully 14 ft. from its lowest position.

The passenger accommodation, which is between the upright platform and the outside girders, will be fitted with neat teak grating seats, placed against the inner stanchions. The vessel will be capable of carrying about 300 passengers and eight loaded carts and horses, or the same number of passengers and four loaded lurries and three loaded carts and horses, or if passengers only, 600 to 700.

The object of a ferryboat built after the foregoing description is to supersede the present inclined slips and approaches necessary to ferry stations, and consequently to diminish the wear and tear in horses, carriages and haulage. It obviates the necessity for the use of valuable ground requisite for such slips, and also enables passengers and goods to be carried with greater economy and facility and landed on the same level and height as the adjoining quays, and by its adoption the ferry steamer is not confined to a special berth as at present. It is also well adapted for the conveyance of troops, cavalry, and ordnance between the shore and war vessels lying in the harbor, since cargo can be shipped at any level and discharged at any level within the range of action of the elevating deck.

The propelling machinery, which is located amidships at each side of the vessel, will consist of two independent sets of surface-condensing triple-expansion engines of the most recent type, each set to be coupled with its own line of propeller shafting, running fore and aft, and each shaft to carry two propellers—making four propellers in all, *i. e.*, two at each end of the vessel. The indicated horse power of the propelling engines will be about 400 collectively.

Provision has been made so that in the event of either set of engines becoming disabled, the remaining set will be able to work the vessel, and thus avoid delay. Steam will be supplied from two horizontal tubular boilers, constructed throughout of Siemens-Martin steel, and to the Board of Trade requirements, for a working pressure of 150 pounds per square inch. They will be fitted with Brown's patent ribbed furnaces. The engines for raising and lowering the platform will be a separate set of surface-condensing triple-expansion, similar in type to those for propelling, and placed in the center of the vessel. Steam will be supplied from the same boilers as the propelling engines. The latter engines will drive two lines of horizontal shafting, running fore and aft, and placed over the propelling shaft. On the shafting gearing is fitted to drive the screws for raising the platform. These screws are placed inside of the upright columns. The gearing of the platform is so designed that a variation of speed can be obtained, according to the nature and extent of the load. The air and circulating pumps will be worked by separate engines, as these are necessary, owing to the short time the vessel is under steam each trip.

In view of the horse traffic that will cross by the boat, special precautions have been taken to do away, as far as possible, with the noise made by the working of the gearing, waste steam, and from other causes. This absence of noise will also prove a great advantage to the passengers.—*Industries.*

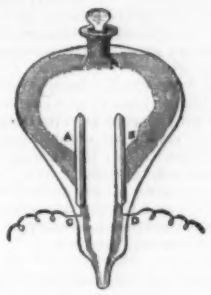
BLEACHING DURING ELECTROLYSIS.

By H. N. WARREN, Research Analyst.

WHILE recently demonstrating upon the electrolysis of water, I caused the acidulated water contained in the voltmeter which was employed for that purpose to be colored blue by the addition of a small quantity of sulphate of indigo, so that the passage into, and, at the same time, the collection of the gases in their respective tubes, might be the more readily observed.

On decomposition of the water being accomplished by the aid of four Bunsen cells, it was observed after the lapse of a few minutes to have assumed an entirely greenish tint, which almost directly afterward completely disappeared, leaving the water perfectly colorless.

After the performance of several experiments, with a view of ascertaining the effects on a more efficient scale, the following apparatus was devised: As shown in the diagram, it consists essentially of an ordinary separating funnel, into the sides of which are secured, by fusing, two thick platinum wires, namely, C and D; these are connected with two graphite pencils, A and B, the surface of each being prepared by introducing the same into a concentrated solution of platinum nitrate, and afterward heating to redness, out of contact with air. On connecting the extremities of the platinum wires with a battery consisting of four Bunsen cells, and having, previous to this, introduced into the globe about half a liter of an acidified and concentrated solution of sulphate of indigo, after the lapse of a quarter of an hour, the blue color, which, at the commencement of the action, was of the usual deep tint natural to indigo, had become transformed into a perfect green, which, as in the former experiments, speedily became colorless. Turmeric tincture of yellow berries, logwood, and cochineal extracts were also as successfully bleached. In a further experiment a piece of indigo-dyed cloth was suspended between the carbon poles, and at the termination of two hours was al-

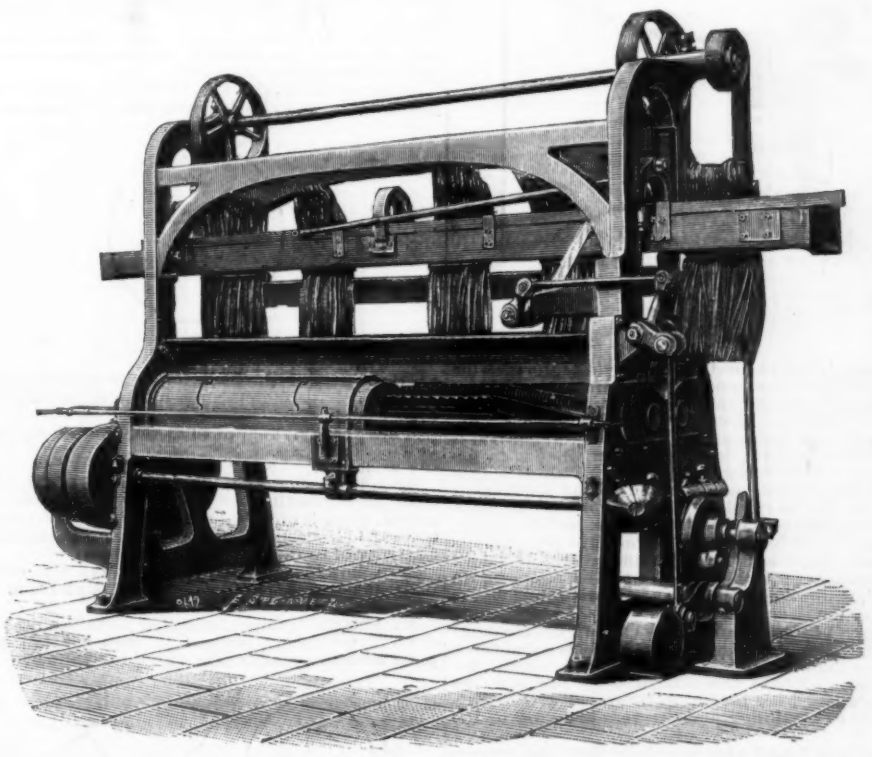


most destitute of any blue coloration. Several samples of raw yellow cotton were also successfully bleached when exposed to the same action; while nitrogenous products such as wool, and also solutions of the various unrefined sugars, experienced little, if any, change.—*Chem. News.*

MACHINE FOR BREAKING FLAX.

THE two machines shown at the Paris exhibition by the Compagnie de Fives-Lille for breaking flax are so arranged, says *Engineering*, that one operates on the points of the stalks, and the other on the heads. They are composed principally of two drums armed with fine blades, with pallets and arcs of copper, which engage with each other and between which the flax to be broken goes upward and downward. These drums turn in opposite directions, and their speed of rotation, which must vary according to the kind of flax to be worked, can be varied by means of change wheels. The drums, in turning, break the straw of flax into small pieces, which are thrown away from the textile filaments and fall under the machine. The straws of the flax are held in breaking machines or presses, which are placed in a horizontal slide moving vertically in guides formed by the frame of the machine. A cam makes the presses move intermittently at the proper moment in the horizontal slide, and this receives a rising and falling movement from another mechanism. Each press is submitted to four successive operations upon each of the machines. The height of travel of the slide carrying the presses is variable at will, according to the length of the flax to be treated. The number of rises of the slide can be varied between four and six per minute, according to the difficulties experienced in breaking and the speed at which the work must be done.

The quantity of flax put into each press is about 1 lb., and from 2,600 lb. to 4,000 lb. can be treated in a day of ten hours. The two machines require the attendance of five workmen. Two place the flax in presses at the entrance of the first machine, two turn the flax in the presses at the entrance of the second machine, and one takes the completed material from the second machine. Other workpeople are required to bring and remove the material. Between the first and the second machine, and beyond the latter, there may be arranged heckling machines, and in this way the flax may be completely broken and heckled at one pressing.



FLAX SCUTCHING MACHINE—PARIS EXHIBITION.

SMOKELESS POWDER.

IN February of this year the *Deutsche Heeres-Zeitung* gave some interesting particulars of the new, almost smokeless powders which are being made by the united Rhine and Westphalian factories. With a 0·5 cm. Krupp gun, 35 calibers long, an initial velocity of 527 meters was given to a projectile of 18 kilog. with 3·9 kilog. of the powder, under a pressure of 1,955 atmospheres. Our contemporary now reports that, at a subsequent trial with the same gun, a projectile of 18·15 kilog. received an initial velocity of 542 meters with a pressure of only 1,942 atmospheres, 4 kilog. of the powder being used, while, when the charge was increased to 4·5 kilog., the velocity was 586 meters, and the average pressure 2,300 atmospheres. The following are the results with another variety of the same large grain powder. With a 12 cm. gun and a projectile of 26·2 kilog.: Charge, 5 kilog.; velocity, 472 meters; pressure, 1,240 atmospheres. Charge, 7·5 kilog.; velocity, 621 meters; pressure, 2,270 atmospheres. Gun of 13 cm. and projectile of between 30·01 and 30·27 kilog.: Charge, 5·5 kilog.; velocity, 512 meters; pressure, 1,340 atmospheres. Charge, 6·5 kilog.; velocity, 625 meters; pressure, 2,010 atmospheres. Gun of 15 cm. and projectile of 51·5 kilog: Charge, 10 kilog.; velocity, 501 meters; pressure, 1,630 atmospheres. Charge, 14 kilog.; velocity, 617 meters; pressure, 2,550 atmospheres.

THE TEREDO IN SOUTH AFRICA.

IN a recent issue of the "Abstracts of Papers" prepared for the Institution of Civil Engineers, London, is the following note drawn from a paper read before the South African Philosophical Society:

Greenheart (*Nectandra rodiæi*) and the sneezewood of South Africa (*Pteroxylon utile*) have long enjoyed the reputation of resisting the attacks of marine worms, but the author has discovered positive proof that both of these woods, under certain conditions, can be ruined by the *Teredo* and by the *Chelura terebrans*. (*Limnoria t.* is not known to occur in South African waters.)

About the year 1885, Mr. J. S. McEwen, then district engineer on the railway from Port Elizabeth to Uitenhage, noticed that the sneezewood piles of a bridge over a tidal stream not far from Zwartkop's station were diminished in section close to the low water mark. On minute examination it was found that the teredo had attacked the piles to such an extent that he was constrained to recommend their removal and substitution by iron. The author exhibited a piece of one of the piles referred to, in which the work of the teredo could be very easily traced.

In 1878 the Port Elizabeth Harbor Commissioners had two jetties constructed from the designs and under the superintendence of Sir John Coode, Vice-President of the Institute of Civil Engineers. For the most part wrought iron was used, but it was decided that the seaward ends, known as the V-heads, should be of greenheart, and with this material, excellent of its kind, the work was carried out. Having lately to make a detailed inspection of the jetty, the author noticed that which at first seemed to be signs of decay in one of the horizontal pieces, and on cutting into it with an adz found it to be completely honeycombed for about an inch deep with the tunnels of the teredo. On further examination it was found that all the horizontal timbers at low water mark had been attacked in a like manner. In the vertical pieces and piles it was noticed that though the worm had entered them, its progress was small as compared with the horizontal pieces. The timber frame placed as a fender outside the iron portion of the jetties was next examined. The author there found not only the teredo, but, in vast

numbers, the destructive little creature known as the *Chelura terebrans*, which invariably commences its destructive work at the ends of the timber, or where one piece comes into contact with another. In this way the chelura, although the actual area destroyed by it is comparatively small, becomes more injurious to a framed structure than does the teredo. Since his first inspection the author has made numerous examinations of these works, and is convinced that before very long the question will have to be considered of replacing the timber work, which cost, for the two jetties, £25,000.

ZIGANG'S POLYPHONE.

IT is easy to establish by direct experiments that sound is produced by the vibrations of a flexible system, cords, plates, etc., and that these vibrations are transmitted to our ear through the intermedium of the air. The sound is more or less musical according to the number of the vibrations.

Simple musical sounds are produced by regular vibrations, as is shown by means of a tuning fork provided with a mirror, which permits of an analysis of the motion of the metallic branches. As for human speech, that is produced by vibrations of an extreme complication, the theory of which is as yet far from being definitely established.

In order to obtain musical sounds, it is therefore necessary to produce vibrations of the air, either through the introduction of cords, as is done in the violin and piano, or by acting directly upon the air, as is done in organs and wind instruments.

The applications of the telephone have shown not only that a thin sheet of iron, placed in a medium where sonorous vibrations exist, vibrates exactly like the surrounding air, but also that such vibrations, as complicated as they may be, can be transmitted through the intermedium of electricity.

On another hand, the electric current furnishes a simple means of producing rapid vibrations that are utilized, for example, for keeping up the motion of an armature for vibrating bells, etc., but we do not think that any one previous to Capt. Zigang has conceived the idea of applying the electric current to the direct production of sound.

Before going further and occupying ourselves with the electric production of music, which forms the basis of this article, we shall have a few words to say concerning the latest improvements in Capt. Zigang's electric trumpet, by means of which he has carried out his idea, and which produces a very clear and much more musical sound than his first apparatus, which was scarcely more than one for demonstrative purposes.

The mounting of the new system is entirely metallic, thus rendering the apparatus incapable of getting out of order (Fig. 1). The sound obtained is more musical

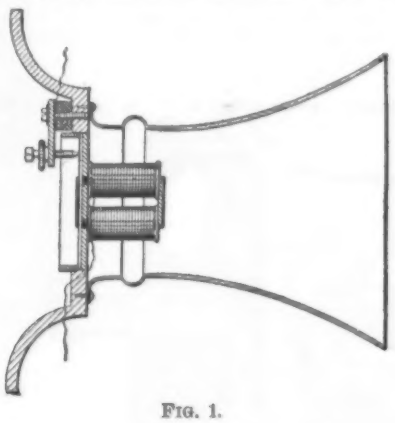


FIG. 1.

than formerly, on account of the inertia of the metallic pieces, which do not assimilate the vibrations of the diaphragm as wooden mountings do.

Let us briefly examine the qualities of the sound obtained with this instrument, as such an examination is indispensable for the understanding of what is to follow. The inventor has succeeded in giving a definite pitch to the musical sound emitted by the instrument, thanks to the exact determination of the elements that are capable of varying such pitch, and which are as follows: (1) thickness of the armature plate; (2) its peripheric compression; (3) its diameter; (4) the weight of the armature; (5) the capacity of the resonator in which the vibrations of the plate are produced; (6) the tension of the electric current.

The cores of the electro-magnets are of small diameter. There has been given to the bobbins a resistance much less than the total resistance of the circuit, because the rapidity of the interruptions prevents the electro-magnet from becoming saturated and demagnetized at every closing and at every breaking of the circuit.

It has been found experimentally that the proportions which yield the best results are those given by the formula

$$\frac{R + n\,r}{4}$$

R being the resistance of the line, and r the internal resistance of each element.

In the ordinary models of the trumpet, the pitch of the sound given by the apparatus, 1⅛ inch in diameter, sensibly approaches *la* (normal diapason), and the current interruptions take place about 450 times per second.

The *intensity* of the sound obtained with the electric trumpet is, up to a certain limit, sensibly proportional to the tension of the electric current, that is to say, to the e. m. f. of the battery. It increases again with electro-motive forces and current intensities greater than those that are necessary for saturating the electro-magnet. The reason is that, seeing the multiple interruptions in a unit of time, the current does not reach its final value.

The *timbre* of the sound depends especially upon the platinized point of the regulating screw against which the plate abuts after every attraction. This quality varies with the medium in which the sounds are produced. A resonator and a metallic mounting give the timbre of a trumpet with vibrating plate operating in compressed air.

When the mounting is of wood, or when the base is placed upon a sonorous box, the timbre is softer. Resonators of great capacity render the sound dull. A reduction of the diameter, by modifying the pitch of the sound, renders the latter clearer and very distinct.

For the purpose of extending the application of the electric trumpet as an intense calling signal, it has appeared necessary, from the first, to endeavor to reenforce the sound. To reach such a result, it seemed natural that the dimensions of the parts should be increased. In fact, an increase of the diameter permits of the use of a more powerful electro-magnet, and the sound becomes intenser; but the increase of the diameter of the vibrating surface leads to a limit that cannot be exceeded, because plates of wide surface emit grave sounds that do not propagate so quickly as sharp notes. It therefore became necessary to find another means of attaining the end proposed.

Now, upon examining the manner in which the vibrations of the plate are transmitted to the exterior, it is remarked that the vibrations are produced in a very limited space, still further reduced by the presence of the electro-magnet.

The instruments that give musical sounds all have spacious resonators in which the sounds become amplified as in all copper piston-instruments.

By increasing the capacity of the resonator of the electric trumpet, the same results are reached. The presence of a metallic bell gives the sound an intensity that renders it perceptible at several hundred yards.

We may add that the Zigang trumpet is now steadily replacing the vibrating bell in most of its applications, and is often used conveniently with the latter for giving signals that are very distinct from each other. The fixedness of its parts renders it valuable for application to trains in motion or to campaign telegraph wagons, in which it remains underangeable and mute, whatever be the more or less abrupt motions of the unstable bodies to which it may be attached.

When a slightly resistant electric trumpet forms part of the primary circuit of an induction coil, and the induced wire of this coil is connected with a line of several thousand ohms' resistance, passing through a magnetic telephone, the sound emitted by the latter is sufficient to serve as a call signal. This again is an application that permits of avoiding complications in long distance telephone installations.

Let us now return to the polyphone. This is an electric trumpet of which the inventor has just made a special adaptation, to which we call the attention of our readers, because it presents a characterized scientific interest in opening to electricity the entirely new prospect of a direct production of music, while the telephone merely repeats the sounds that it receives.

We have above stated, *apropos* of the pitch of the sound, that an increase or diminution of the vibrating surface renders the note more or less grave or shrill. Now, this surface can be reduced mechanically by pressing any rigid body whatever against the plate. To this effect, an electric trumpet is so arranged that the resonator shall be beneath and the plate above, and well within reach of the hand.

If the point of a metallic style be applied to the point, *a* (Fig. 2), of the plate supposed to be in motion,

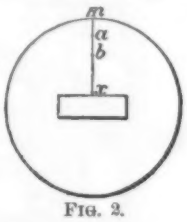


FIG. 2.

a certain part of the surface will be immobilized, and the pitch of the sound will vary to a degree dependent upon such immobilized surface.

When the style is applied to the point, *b*, the sound becomes still sharper, and so on until the style touches the armature.

Upon properly graduating the radius, $m\,x$, into divisions corresponding to the notes of the chromatic gamut, there is obtained about an octave of notes, according to the conditions of the homogeneousness and elasticity of the armature plate.

Here, now, is how the inventor has arranged the little musical apparatus that he styles the polyphone.

An electric trumpet, mounted metallically, is fixed upon a mahogany support in such a way that the plate is on the outside (Fig. 3). A resonating tube pro-

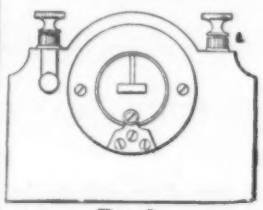


FIG. 3.

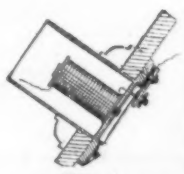


FIG. 4.

jects from the other side and permits the apparatus to assume a position inclined at an angle of 45° in resting on the lower edge of the support and on the circumference of the cylindrical tube (Fig. 4). Two terminals are placed at the upper part of the support and communicate, one of them, with the regulating screw, and, the other with the free wire of the electro-magnet through the intermedium of a small contact button provided with a spring. These terminals are connected with the two poles of a battery of from three to five Leclanche elements in tension.

The polyphone rests upon a table in front of which the person is seated who is to use the apparatus. He holds the mahogany support in such a way that the interior of his left hand shall be opposite the contact button (Fig. 5). If this button be pressed, the appara-

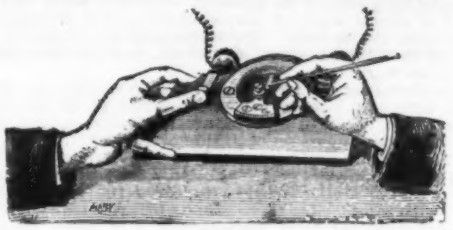


FIG. 5.

tus will give its fundamental sound, which, moreover, may be varied by a third through a simple maneuver of a screw ring that serves to bind the plate upon the resonating tube.

Upon applying the point of the style to the point, *x* (Fig. 2), the same note is obtained as the one that the fundamental sound gives, but in the sharp octave. All the notes of the chromatic gamut are thus embraced between *m* and *x*, at smaller and smaller intervals in measure as the center of the diaphragm is approached. Upon displacing the point of the style in a methodical manner, as would be done in tightening or loosening the string of a violin, it is easy to play a large number of musical airs.

The timbre of the instrument approaches that of the clarionet or hautboy.

The apparatus readily lends itself to the execution of the modulations of music. For short notes the style is placed upon the point corresponding to the note to be obtained, and the contact button is then depressed. On the contrary, for slurred notes, the button remains depressed, and a rapid movement of the point of the style gives the *nuance*. In order to give expression to a sustained note, it suffices to cause the right hand to tremble slightly, and the motions thus made are communicated to the plate and give rise to beats that are very agreeable to the ear.

Capt. Zigang's polyphone, seeing its slight scope, makes no pretensions to be a musical instrument, but it is an interesting apparatus which realizes the execution of a new idea—*the application of electricity to the direct production of music.*

Capt. Zigang's apparatus for demonstrating this principle consists of a mahogany support carrying 36 elementary apparatus giving three complete octaves of notes. As with the same diameter one entire octave can be produced, the resonators differ by three calibers only. The diameter for the grave octave is 2¼ inches; for the sharp octave, 1 inch; and, for the intermediate octave, 1¼ inch. The electro-magnets of the elementary apparatus have a uniform resistance of 0·8 ohm.

In order to immobilize a portion of the plate of each trumpet, the inventor employs a small strip of brass carrying at one of its extremities a screw whose point bears against the plate (Fig. 6). Two wooden screws,

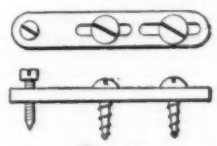


FIG. 6.

which engage with the mahogany support, permit of fixing this accessory, while they at the same time allow it a longitudinal play for facilitating the regulation.

Each trumpet is connected with the transmitting mechanism, which consists of a piano keyboard, each key of which is a commutator. The current is furnished by two bichromate elements.

The operation of the system is easy to understand. When a key is depressed, a current is sent into the apparatus that corresponds to such key, and the instrument renders the note for which it has been tuned. The depression of several keys at once has the effect of furnishing the electro-magnets with currents derived from the main circuit. The instrument behaves like an organ whose sounds have a uniform timbre, which here is that of the hautboy.

Here, then, is a new principle established. *It is possible, with media entirely electric, to produce attuned musical sounds.*

The system in operation in the Machinery Palace of the exposition, where Capt. Zigang has on exhibit all his apparatus, is, properly speaking, neither an organ nor even an element of an electric organ, but an apparatus of demonstration showing the possibility of solving the problem in a wider sense.—*La Lumiere Electrique.*

A NEW ELECTRO DYNAMICS.

By JOHN LOWE, Chief Engineer, United States Navy.

IT is impossible to-day to predict for to-morrow anything like what electricity may have in store for mankind. Its progress is so rapid that even prophecy is outrun, but yet it is certain that, allied with kindred topics, electricity in the near future will become the agent of new comforts, new powers, and indeed of a new civilization. Electrical science has not, however, kept pace with electrical experiment, but rather is in the same chaotic state that thermal science once was, in the days of Priestley and of phlogiston; in fact, it is not so much a help as it is a hindrance to practical, concrete, and exact knowledge.

The purpose of this paper is to point this out, and then to make suggestions looking toward a remedy.

To be entirely fair, it is first of all proper to refer to his prefaces; then, after this, to quote the words of the foremost and most widely accepted authority upon this subject, S. P. Thompson, in "Elementary Lessons;" taking therefrom nine definitions, numbering each for easy reference; the object being to exhibit the exact state of the science at this present date.

1. *Unit of Force.*—The unit of force is that force

which, acting for one second, upon a mass of one gramme, gives to it a velocity of one centimeter. It is called a dyne.

2. *Unit of Work.*—The unit of work is the work done in overcoming unit force, through unit distance; that is in pushing a body through a distance of one centimeter against a force of one dyne. It is called an erg.

3. *Unit of Potential.*—Being measured by work done, in moving a unit of plus electricity against the electrical force, the unit of potential will be measured by the unit of work, viz., the erg.

4. *Difference of Potential or of Electromotive Force.*—Potential is work done, upon a unit of electricity. Hence unit difference of potential exists between two points, when it requires the expenditure of one erg of work to bring a unit of plus electricity from one point to another, against the electrical force.

5. *Unit of Electricity.*—One unit of electricity is that quantity which, when placed at a distance of one centimeter from a similar and equal quantity, repels it with the force of one dyne.

6. *Unit of Resistance.*—A conductor possesses unit resistance, when unit difference of potential between its ends causes a current of unit strength, that is, one unit of quantity per second, to pass through.

7. *Unit of Capacity.*—That conductor possesses unit capacity which requires a charge of one unit of electricity to bring it to unit potential.

8. *Capacity.*—The electrostatic capacity of a body is measured by the quantity of electricity which must be imparted to it, in order to raise its potential from zero to unity.

A small conductor will not want so much as one unit of electricity to raise its potential from zero to unity, it is therefore of small capacity; while a large sphere will require a large quantity to raise its potential to the same degree, and would therefore be said to be of large capacity.

PRACTICAL UNITS.

9. *Resistance.*—The ohm = 10^9 absolute units of resistance, and theoretically the resistance represented by the velocity of one earth quadrant per second.

In study, the first great stumbling block the student encounters is the unit of quantity, which is so obscurely defined that ordinarily it is impossible to conceive of how much, or of what kind, the unit is; and as a consequence, all definitions into which quantity enters are alike obscure, and without point. Again, after defining, with great exactness, the units of force and of work, in definition 4 the terms potential and of electromotive force are badly mixed up, and the definition says in effect that one unit, either of electromotive force or of potential, is each equal to one erg, a force to an effect; and thus definitions 1, 2, 3 are contradicted, confusion commencing at this point.

As a consequence of this confusion of terms, definition 8 may be forced to say that a small quantity of electricity is as potent as a large quantity.

In definition 9, resistance is explained to be a velocity throughout; the student is struck with the large number of units and terms employed to measure and describe electricity. These things are cited as instances of the perplexities which lie in wait for the student.

Let us imagine the author of Ohm's law once again alive and at work. Imagine his wrath as he might exclaim, "Shades of the immortal gods! what is this ohm that is called by my name? What has become of the simple law upon which I spent so much labor? See how it is disguised. You divide one volt by one ohm and call the result one ampere. You might as well divide one inch by one foot, and call the result one dunce, for the ratio is not unity, but $\frac{1}{12}$, the units are not homogeneous, the terms are meaningless and arbitrary, and unless translated, the result is error. My fame rests upon my labors, my monument is my law, and it is no honor to me to have my name used to designate, but not describe, and thus becloud my own labors."

These objections and many others, the same obscurity of statement and of vision, are to be found in all works upon the subject.

It is easy to point out the cause; although at the outset writers recognize the error, yet for want of a better conception, they drift into treating the subject as though electricity was a material substance, to be measured and defined accordingly.

Let us make a short stop right here to inquire, what is it that a dynamo delivers and an electromotor receives. Is it compressed air, steam, water, or does the wire, without the intervention of any agent, convey energy, pure and simple?

Truly does Fleming remark, "The dynamo upsets a great many theories." Electricity is in no sense a substance, but, akin to heat, it is a manifestation of energy, and not only a manifestation, it is more:

Electricity is Energy.

Accept this definition, and bright sunshine dispels all clouds obscuring our vision, and at once we walk in the right path. Indeed, our very first thought is, if electricity is energy, then it may be measured as energy is measured, and if so, then, like the thermal unit, there is an electral unit which has a dynamical equivalent; and thus easily we arrive at a fundamental truth.

We would then seek the value of this equivalent; and to do this, let us borrow a favorite illustration of the text books:

Fig. 1 is an ideal dynamo, consisting of the armature A B, of unit resistance, and the length of one centimeter, together with the branches, CDFG, having no resistance, and such permeability that the field of force is one dyne per square centimeter.

Because of this force, with the effort of one dyne, let us move the armature at the rate of one centimeter per second.

An electromotive force of one dyne is set up, which compels a current to pass through the armature with a velocity of one centimeter, which velocity in turn induces a resistance of one dyne, in overcoming which resistance the current performs the work of one dyne centimeter, or one erg; precisely that performed by the hand, in moving the armature.

Now, then, by way of further illustration, let the resistance be two dynes instead of one. Because the unit field is still one dyne, with the force of one dyne the armature is moved at the rate of two centimeters, which induces an electromotive force of two dynes, compelling the current to overcome a resistance of two dynes, performing a work of two ergs per second.

This illustration depicts, that which may mathematically be proved, that the unit of quantity is one erg of work. But we already know, and must remember, that energy always consists of two factors, a force factor (p) and a space factor (v), and that any quantity (w) of energy has for value $w = p\,v$.

If now p is a force operating upon one square centimeter or the unit surface, the unit space is one cubic centimeter, and we are able to say:

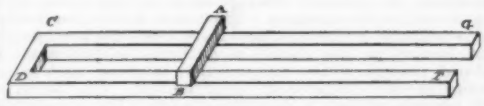
(A) *The unit quantity of electricity is the force of one dyne operating upon one square centimeter through one cubic centimeter; in other words, it is one erg of work.*

The unit of quantity thus being made clear, the obscurity contained in all other definitions is at once dispelled.

For example, the unit of resistance may now be defined:

(B) *The conductor of unit resistance conveys from end to end thereof one erg, in one second, when the electromotive force is one dyne.*

Figure 1



But now it becomes necessary to get at the character of resistance. If a motive force is resisted, it must be resisted by a force, not a velocity, as definition 9 maintains, but a force in the same sense as inertia, acceleration, etc., are forces.

Furthermore, if a motive force (p) impels, and a resisting force (r) resists; p first produces motion, then this result, becoming in turn a cause, produces resistance, and the amount (v) of motion is the ratio between the forces, and we have—

$$v = \frac{p}{r}$$

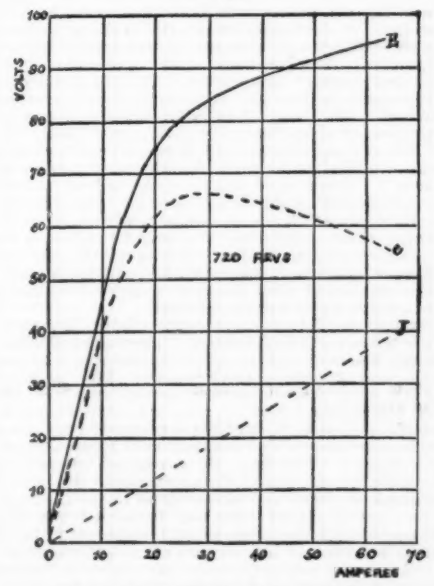
In other words, we have, by our reasoning, arrived at Ohm's law—a result which proves our argument.

But once again, returning to Fig. 1, we find that the armature, moving at the rate of one centimeter, induces the E. M. F. of one dyne, and that moving at the rate of 10^9 centimeters induces one volt, both of which units are defined by the text books to be force units. Why then should the same text books define one ohm, the result of 10^9 centimeters, to be a velocity and not a force? Clearly it is a stumbling block, which it is hard for the student to surmount, if he desires to proceed any better than parrot fashion.

That resistance is a force, and that resistance and electromotive force may be and ought to be measured by the same unit, in the same equation, we desire to prove by again quoting our distinguished authority, S. P. Thompson, in "Dynamo-Electric Machinery."

Fig. 2 is a reproduction from page 363 of a diagram of "Dynamo Characteristics," a method of investigation originated by Professor Hopkinson.

FIG. 2.



TOTAL AND EXTERNAL CHARACTERISTICS.

It will be seen by examination of this diagram that volts are plotted as ordinates upon amperes as abscissæ.

The curve, E, gives at any intersection corresponding values of the total electromotive force and of the current.

The curve, e, gives corresponding values for the terminal electromotive force and of the current.

The ordinate included between these curves is the resistance in *volts*, which are again plotted in the curve, J.

Observe the fact, resistance and E. M. F. both measured by the same unit, the volt; and this work done by distinguished men.

With all proper emphasis, let us here point out that, unless this was done, Hopkinson's characteristics would be impossible, and the rich results therefrom would be unattainable; and it may be proved that the algebra of the subject would be immensely benefited were the same course adopted.

Summarizing: It is hereby claimed for this paper that the following points are for the first time distinctly asserted and proved.

1. That electricity is energy, pure and simple.

2. That the C. G. S. unit of quantity is one erg of energy.

3. That resistance is a force and not a velocity.

4. That the ratio $\frac{\text{E. M. F.}}{\text{Resistance}}$ is a space, and should be so called.

5. That the term potential means too many things, and should be discarded, and a brief term signifying E. M. F. substituted.

6. That E. M. F. and resistance should be measured by the same unit.

7. That distinguished men and advanced investigation already do so.

8. That the C. G. S. units and terms are without other fault than that the units are too small for present practice.

9. That in the effort to substitute practical units, unlike the earlier investigators, later ones have applied to units designations which do not describe.

10. That these practical units are not homogeneous.

11. That were these things remedied, the science of electricity would be greatly simplified; a greater number of workers would understand, and a greater result in invention and discovery would ensue.

If this paper has not proved these things, oblivion is its fate, but if, on the other hand, these things are true, as it is promulgated, as it is discussed, and slowly gathers force as it gathers favor, it will be years before it will produce visible effect.

In the meantime, instruments now in use cannot be and ought not to be discarded; for they can be made to convey correct physical meanings by the simple transposition of the decimal point.

The following table is suggestive of this, and of many other things.

The value of the dyne is given in definition 1: Similarly, one pound, operating during one second upon one pound, induces 32·2 feet per second. Therefore we have:

$$\text{One pound} = \frac{1}{0{\cdot}00220473} \times \frac{32{\cdot}2 \times 12}{0{\cdot}3937} = 446609 \text{ dynes.}$$

$$\text{One volt} = 10^9 \text{ dynes} = \frac{10^9}{446209} = 224{\cdot}12 \text{ lb.} = \tfrac{1}{10} \text{ ton} =$$

100 kilos nearly.

One ohm = 10 volts = 2241·2 lb. = 1 ton = 1,000 kilos nearly.

And finally, applying such corrections as are necessary so as to make the results exactly 100 and 1,000 kilos, as they ought to be, we have familiar force units available.

REVIEW OF THEORIES OF ELECTRICAL ACTION.*

By Professor H. S. CARHART.

THE physics section of this association congratulates itself because it deals with topics of the most lively and general interest, not only from a practical point of view, but still more from a theoretical one. Even popular interest in electricity is now well nigh universal. Its applications increase with such prodigious rapidity that only experts can keep pace with them. At the same time the developments in pure electrical theory are such as to astound the intelligent layman and to inflame the imagination of the most profound philosopher.

Of the practical applications of electricity it is not necessary to speak. They bear witness of themselves. A million electric lamps nightly make more splendid the lustrous name of Faraday; a million messages daily over land and under sea serve to emphasize the value of Joseph Henry's contribution to modern civilization. Blot out these two names alone from the galaxy of stars that shine in the physical firmament, take from the world the benefits of their investigations, and the civilization of the present would become impossible. The value of the purely scientific work of such men is attested by the resulting well-being, comfort, and happiness of mankind.

But the mind can never rest satisfied with the facts and applications of a science, however interesting and useful they may be. It feels an inward impulse to link the facts into a related whole, to inquire into their causes, to frame a satisfactory theory of their correlation, and so to build on them a true science.

It is, indeed, interesting to study the history of any scientific doctrine and to trace its development from the crude notions of its earliest stages to the more refined conceptions of later periods, comporting indefinitely better with the marvelous processes of nature. Such a history we have in the views which have been held regarding the nature and action of electricity. The transition from the glutinous effluvium of the sagacious Robert Boyle to the magnetic and electric waves of the present, traversing the omnipresent ether with the velocity of light, is not an easy one to make, even in a period of two hundred years.

For more than twenty centuries natural philosophers had nothing better than the emission theory to account for the attraction exhibited by rubbed amber and other similar substances. Their notion was that the rubbing of the amber caused it to emit an effluvium which returned again to its source and carried light bodies back with it.

In one respect this fanciful attempt to explain electrical attraction deserves commendation, for it evinces a mental inaptitude to account for physical actions "at a distance," or without some intermediate agency. Later philosophers, satisfied perhaps too easily with mathematical explanations founded on the observed laws of attraction and repulsion, and not demanding a medium, did not feel the same intellectual necessity of filling the space between bodies acting on one another, either with emanations from those bodies or with an invisible, imponderable medium, suspected by no sense of man, but required only to meet a demand of his highest intelligence. For when the Newtonian philosophy had made some progress, the doctrine of unctuous effluvia was given up, and physicists acquiesced in the unexplained principle of attraction and repulsion as properties of certain bodies communicated to them

* Address by Professor Carhart, Vice-President Section B, American Association for the Advancement of Science, delivered at the annual meeting, Toronto, August 28, 1889.—*The Electrical Engineer.*

by the Divine Being, the mechanism of which they scarcely attempted to explain.

"Many superficial philosophers thought they had given a very good account of electricity, cohesion, and magnetism by calling them particular species of attraction peculiar to certain bodies."*

The discovery by Stephen Grey that "the electric virtue" could be conveyed along a wire for several hundred feet without sensible diminution, and the invention of the Leyden jar by Kleist, or Cuneus, had the effect of annihilating many mushroom theories constructed on the slimmest basis of facts. The latter discovery disclosed a power in electricity not previously suspected, and excited the greatest interest in both Europe and America.

At this period Franklin turned his attention to the subject, and "spent more time in diversifying facts and less in refining upon theory" than some of his European contemporaries. In fact, he tells us that he was never before engaged in any study that so totally engrossed his attention and his time. His discovery that the two electricities are always excited in equal quantities, that the charge resides on the glass and not on the coatings of the Leyden jar, and his experimental identification of lightning with frictional electricity, excited the liveliest interest abroad, and secured for him the Copley medal of the Royal Society; while his theory of positive and negative electricity made a permanent addition to the nomenclature of the science. His conceit that a turkey, killed with the discharge of a battery of jars, was uncommonly tender eating, a discovery gravely communicated to the Royal Society by William Watson, is not so well known, and does not appear up to the present to have been verified.

We cannot agree with him, I am sure, when he says: "Nor is it of much importance for us to know the manner in which Nature executes her laws; it is enough if we know the laws themselves."

For the pursuit of the manner in which Nature executes her laws is the distinguishing characteristic of the science of the present day. It has led to most brilliant discoveries, and bids fair to do more than all other agencies combined to show the intimate and necessary relations existing between the different branches of physics. We need to be reminded often that accumulated facts do not constitute a science; and that utility is not the highest reward of scientific pursuits.

A bit of polished marble plucked from the ruins of the Roman Palatine Hill is an interesting relic; but how much more interesting to reconstruct the palace of Nero and to see this fluted marble in its proper and designed relation to the whole, of which it was once a necessary part. Science is constructive. Laws are derived from an attentive consideration of facts; generalizations group laws under broader ralationships; and great principles unite all together into one related, impressive whole.

From the time when the famous Boyle caught sight of a faint glimmer of electric light to the present, physicists have been in pursuit of the connection between light and electricity. As early as Newton's time, the ether was conceived by some to be a subtile medium confined to very small distances from the surfaces of bodies, and to be the chief agent in all electrical phenomena. "But," says Priestley,† "the far greater number of philosophers suppose, and with the greatest probability, that there is a fluid, *sui generis*, principally concerned in the business of electricity. They seem, however, though perhaps without reason, entirely to overlook Sir Isaac Newton's ether; or if they do not suppose it to be wholly unconcerned, they allow it only a secondary and subordinate part to act in this drama." Among the branches of knowledge that this writer recommends as likely to be of especial service in the study of electricity is the doctrine of light and colors. The invention of the voltaic battery, and Sir Humphry Davy's celebrated experiment in producing the electric arc, stimulated inquiry in this same direction. Mrs. Somerville, Morrichini, and others, sought to produce magnetism by means of sunlight, but ultimately, as is now known, without success. Notwithstanding these negative results, Faraday had such a "strong persuasion derived from philosophical considerations" of a direct relation between light and electricity that he resumed the inquiry in a most searching manner, with the happy result of discovering the rotation of the plane of polarization of light by means of magnetism.

"Thus is established," he says,‡ "a true, direct relation and dependence between light and the magnetic and electric forces; and thus a great addition [is] made to the facts and considerations which tend to prove that all natural forces are tied together, and have one common origin."

It was thus reserved for Faraday to make those discoveries and to obtain that insight into electric and magnetic action which were needed by his great disciple and interpreter, Maxwell, to construct a most marvelous theory of the connection between these two departments of physical science.

Respecting the failures to obtain magnetism from the direct action of sunlight, to which allusion has been made, Maxwell says that we should not expect a different result, because the distinction between magnetic north and south is one of direction merely; that there is nothing in magnetism indicating such opposition of properties as is seen at the positive and negative poles of a battery in electrolysis; that even right and left handed circularly polarized light cannot be considered the analogue of the two poles of a magnet, for the two polarized rays when combined do not neutralize each other, but produce plane polarized light.

It may be said, however, that if a right-handed circularly polarized ray produces magnetism in one direction, and a left-handed ray in the opposite, then the combination of the two rays may neutralize their magnetic effect, inasmuch as plane-polarized light may have no magnetic influence. Professor J. J. Thomson has lately shown mathematically that a circularly polarized ray does have a magnetic effect, but that it is so small, even with strong sunlight, as to be much beyond the limits of experiments; and Mr. Shelford Bidwell has produced a bar of iron in such an exquisitely sensitive magnetic state that magnetic changes are certainly produced in it by the direct action of light. This he has secured by rendering the bar more susceptible to magnetic influences in one direction than the other. We may not, I venture to affirm, be without hope that magnetism and electric currents may yet be evoked by the direct agency of sunlight.

Faraday was deeply convinced that space had magnetic properties, and that the space or medium around a magnet is as essential as the magnet itself, being a part of the complete magnetic system. To him all magnetic and electric action took place by contiguous particles along lines of force. "What that magnetic medium, deprived of all material substance, may be, I cannot tell," he says,* "perhaps the ether." No doubt existed in Faraday's mind that these lines represent a state of tension; but whether that tension is a *static* state in the ether, or whether it is *dynamic*, resembling the lines of flow of a current between the poles of a battery immersed in a conducting fluid, was uncertain. He inclined, however, to the latter view. He was thus led to advocate, though not without hesitation, the physical nature of lines of force.

Faraday's discoveries and his method of regarding all magnetic and electric actions as propagated through a medium by means of contiguous parts have been of the utmost productiveness. They have revolutionized the science of electricity, and have been the most potent factors in the genesis of a theory, including all radiant energy, which has recently received such remarkable and conclusive confirmation. His name has become almost a household word. His earnest, unselfish life has added unnumbered millions to the world's wealth. His ideas and words, which have been instruments in the hands of philosophers, have become the current coin of the commercial tyro, who talks as glibly about lines of force and the magnetic circuit as if he really knew something about them.

Fruitful as Faraday's ideas were, they yet awaited a mathematical interpreter for their highest development. A good Providence sent James Clerk Maxwell, whose brilliant mathematical ability was equaled by his philosophic insight, his poetic feeling and imagination, his profound sincerity and his great sympathy with nature. Here him sing at Aberdeen:

"Alone on a hillside of heather,
I lay with dark thoughts in my mind.
In the midst of the beautiful weather,
I was deaf, I was dumb, I was blind,
I knew not the glories around me,
I counted the world as it seems,
Till a spirit of melody found me,
And taught me in visions and dreams."

"For the sound of a chorus of voices
Came gathering up from below,
And I heard how all nature rejoices,
And moves with a musical flow.
O strange! we are lost in delusion,
Our ways and our doings are wrong,
We are drowning in willful confusion
The notes of that wonderful song."

To appreciate Maxwell's relation to theories of electrical action, it is desirable to take a retrospect of the views that have been held regarding its nature. Three periods in the history of these views may readily be distinguished. The first was introduced by Dr. Gilbert in 1600, and it lasted for about 225 years. The little that was known previous to Gilbert constitutes only the preface or introduction to the history proper. Nearly three-fourths of this period was utterly barren and unfruitful. It knew nothing better than unctuous effluvia and electric atmospheres. In the latter half of the period the Newtonian philosophy had become the orthodox doctrine. The great success attending the mathematical investigations, founded upon the law of inverse squares, naturally carried with it the acceptance of the underlying hypothesis of "action at a distance." There were not lacking, indeed, men of deeper philosophic insight who denied this doctrine, which they looked upon as entirely unphilosophical and which must utterly bar the way to any inquiry into the process by which the law is executed. Action at a distance by attraction or repulsion, varying inversely as the square of that distance, means an ultimate fact not admitting of further analysis.

The second period was one of contention. It began, not with the important discovery of current electricity, nor of the electro-magnet, but with the philosophical methods and concepts of Faraday. The physical postulates of the mathematical school were entirely alien to the views which he adopted. "Faraday, in his mind's eye, saw lines of force traversing all space where the mathematicians saw centers of forces attracting at a distance; Faraday saw a medium where they saw nothing but distance; Faraday sought the seat of the phenomena in real actions going on in the medium, they were satisfied that they had found it in a power of action at a distance impressed on the electric fluids."† Prior to Faraday the supporters of a medium to explain electric and magnetic action were always thrown out of court for lack of evidence; Faraday gave them a legal standing by furnishing the facts and evidence on which they could well afford to base their case.

The corpuscular theory of light, which had shown such remarkable vitality, was now in the last stages of a fatal disease, due to indigestion and lack of assimilation. Foucault finished it off in 1865 with his crucial experiment to decide upon the relative velocity of light in the air and water. The undulatory theory was thus fully established, and the doctrine of radiant energy in general began to be clearly apprehended. The grand generalization of the conservation of energy was looming up all along the horizon of science, as the towers and spires of a great city appear to rise out of the sea to a traveler approaching the land. Victory was ready to perch on the banners of an army contending for the ether doctrine—not a decimated army, but one constantly augmenting in numbers by deserters from the enemy. At this period, sixteen years ago, appeared the epoch-making book of Maxwell on "Electricity and Magnetism." Its author professes only to translate Faraday's ideas into mathematical language; but he did vastly more than this. He demonstrated mathematically that the properties of the medium required to transmit electro-magnetic action are identical with those of the luminiferous ether. It would be unphilosophical, he remarks, to fill all space with a new medium whenever any new phenomenon is to be explained; and since two branches of science had independently suggested a medium requiring the same properties to account for the same phenomena in each, the evidence for the existence of a single medium for both kinds of physical phenomena was thereby greatly strengthened. The step from identity of the medium to identity of phenomena, that is, that light itself is an electro-magnetic phenomenon, though it may now seem to be a short one, must nevertheless, upon careful consideration, always be accepted as evidence of the greatest genius. To walk in Maxwell's footsteps now and take the very steps he took is one thing, and a comparatively easy one; but to make original explorations into unknown regions of nature, and to tread where no human being has ever before set foot, is quite another thing. The electro-magnetic theory of light must be regarded as a great generalization, inferior only to that greatest one of all time—the conservation of energy.

The principal criteria upon which Maxwell relied for the confirmation of his theory may be briefly enumerated:

1. An electro-magnetic wave or undulation is propagated through the ether with a velocity equal to the ratio of the electro-magnetic to the electrostatic unit of quantity. If light is an electro-magnetic phenomenon, its velocity must also be equal to this same ratio. The very close approximation of the one to the other, as determined by a variety of methods, has been known for some time.

2. The specific inductive capacity, K, of any trans parent dielectric should equal the square of its index of refraction. The discrepancies at this point are so great that all one can say in the most favorable case is that K is the most important term in the expression for the refractive index, while in other cases no confirmation whatever can be drawn from this class of evidence.

3. The magnetic and electric disturbances are both at right angles to the direction of propagation of the wave and at right angles to each other. The mathematical form of the disturbance agrees with that which constitutes light in being transverse to the direction of propagation. Further, the *electric* disturbance should be perpendicular to the plane of polarization of plane-polarized light.

4. In non conductors the disturbance should consist of electric displacements, but in conductors it should give rise both to electric displacements and electric currents by which the undulations are absorbed by the medium. Most transparent bodies, it is true, are good insulators, and all good conductors are opaque. The degree of opacity is, however, far from being proportional to the conductivity.

5. But perhaps the most important criterion of all is the one relating to the very existence itself of a medium. Such a test lies in the *time* element involved in transmission from point to point. Since energy is transmitted from a luminous body, as the source, to another body, which may absorb it, then plainly, if time is required for the transmission, the energy must reside in the medium by which the transmission is effected during the interval between the emission and the absorption. In the emission theory the light corpuscles are the receptacles of the energy and carry it with them in their flight. According to the undulatory theory, the medium filling all space is the receptacle of the energy, and passes it along from point to point by the action of contiguous parts.

Foucault's *experimentum crucis* proved the emission theory untenable. Roemer's observation of the retardation of the eclipses of Jupiter's satellites, when the earth is moving away from Jupiter, is, therefore, a confirmation of the undulatory theory of light and, in consequence, a demonstration of the existence of the luminiferous ether.

At this point the history of the nature of electrical action touches upon the third period

The period upon which we have just entered may not inappropriately be called the period of confirmation. Nothing further appears to be necessary for the complete demonstration and establishment of the electro-magnetic theory of light. The noteworthy experiments of Professor Hertz, of Carlsruhe, are known to all. Rightly conceiving that the reality of electro-magnetic waves would be best established by the same experiments which would also establish the fundamental identity of such undulations with those of light, he had recourse to the principle of resonance or sympathetic vibrations for the detection of these long-period waves. By a device no less remarkable for its simplicity than its effectiveness he produced electrical oscillations of such rapidity that the waves in the surrounding region were short enough to be measured. This he accomplished by attaching to the secondary terminals of an induction coil two rectangular sheets of metal, each supplied with a short, stout wire ending in a small ball. The balls were brought near each other and the discharges of the coil took place between them. Under these conditions the discharge is oscillatory, and the period may be calculated by the formula of Sir Wm. Thomson, published in 1853.*

The receiving apparatus is also of the simplest design, consisting ordinarily of a circle of wire, interrupted at a point with an adjustable opening, and of such dimensions that the waves passing through the circle may set up electrical oscillations in it, synchronizing with those of the transmitting apparatus. The passage of sparks across the narrow opening of the circle indicates an electrical flow; and the necessity of adjusting the size of the circle in order to obtain this flow proves that the forces acting are periodic. The receiving apparatus must in fact be tuned so that the period of an electrical oscillation in it shall correspond with the external impulses absorbed. The intensity of the electric and magnetic disturbances is indicated by the relative length of sparks obtainable.

Equipped with this apparatus, which was installed in a large lecture hall, Hertz found not only that his tuned receiver responded to the impulses of the transmitter in the precise manner pointed out by theory, but that the sparks showed a series of maximum and minimum values recurring in periodic order as the receiver was carried further away from the source of the disturbances. The astounding fact was thus brought out that these electro-magnetic waves were reflected from the thick wall of the room,

* Priestley's Hist. of Elec., vol. ii., p. 18.
† Hist. of Elec., vol. ii., p. 24.
‡ Exp. Researches, 2,224.

* Exp. Researches, 3,277.
† Maxwell's Elec. and Mag., p. x.

* Math. and Phys. Papers, vol. i., page 540.

and that the combination of the direct and reflected systems produced stationary waves with loops and nodes that could be traced out by the responsive circle of wire. In this manner wave lengths were measured down to 60 cms., and the *time element* was experimentally detected in the propagation of electrostatic and electro-dynamic induction. It was demonstrated that the disturbances producing the waves are at right angles to direction of propagation, as Maxwell predicted, and as interference phenomena show them to be in light. Hertz has also found an electro-dynamic shadow cast by an iron post; he has verified the laws of reflection from plane and concave metallic reflectors, and has shown that electric waves suffer polarization and refraction in a manner exactly analogous to light. Professor Fitzgerald, of Dublin, has added another confirmation of Maxwell's doctrine, demonstrating that the *electric* disturbance is perpendicular to the plane of polarization, as Maxwell's equations require. Finally, the velocity of propagation of these electro-dynamic waves is found to be the same as the velocity of light. Thus not only have all of Maxwell's criteria except the second abundantly confirmed the judgment of the great physicist, but other proofs have been added. Electro-magnetic waves are therefore not merely like light, but they are light. Or perhaps, to speak more exactly, all radiant energy is transmitted as electro-magnetic waves in the luminiferous ether. Electricity has thus annexed the entire domain of light and radiant heat; and, as Professor Lodge says, "has become a truly imperial realm." The difference of wave length in the three classes of phenomena is not a fundamental one. Increase the rate of the electrical oscillations a millionfold in Hertz's experiments, and the waves would not merely resemble light—they would be light. A wire through which such oscillations are surging back and forth would glow with light. Even the long heat waves would be absent, and only those producing the sensations of light and color would remain.

It will be observed that the oscillations of an electric discharge constitute the point of departure for the admirable researches of Hertz; and it is a matter in which we may modestly take a bit of national pride that the first case of electric oscillations was discovered by an American physicist. The oscillatory character of the Leyden jar discharge was demonstrated by Joseph Henry, in 1832, by means of the magnetic effects produced in small steel needles. It was not until twenty-one years later that Sir Wm. Thomson published the complete mathematical theory of such oscillations. They have since been observed directly by means of a rotating mirror. Dr. Oliver Lodge has lately shown that they rotate the plane of polarization of light in one direction and then in the other as they surge back and forth. He has also reduced the number of oscillations from several millions per second to a few hundred by increasing the capacity and the self-induction. The discharge then vibrates within the limits of audibility and produces a musical note.

The well-known experiment of Henry, in which he observed an induction current in a wire stretched parallel to and distant 30 feet from one which served to discharge a Leyden jar, is now seen to have been a case of resonance; that is, the absorption of electric waves by a conductor, producing currents therein. And it is an evidence of the great genius of Henry that he saw, somewhat dimly it may be, but still with a certain degree of rational apprehension, that the induction was transmitted across the intervening space with a velocity comparable only to that of light. He had perchance the divine touch of genius necessary for the great discovery of electro-magnetic waves coursing through the ether; but the way leading to this important physical fact had not then been sufficiently prepared, and its discovery was impossible.

Waves similar to those from a Leyden jar discharge, but of longer period, are sent out from a wire conveying alternating currents. We must conceive of such a wire not simply as affected internally or even superficially by the electric energy surging through it, but as the source from which pulsate outward through the limitless ether great waves of electro-magnetic disturbance. For 800 complete alternations per second, these waves are a million meters, or over 600 miles, in length. They present a marked contrast with the waves corresponding to the D lines of the spectrum, which are only about one five-millionth of a millimeter long.

These long waves from an alternating current represent energy. Through space it is conveyed with the velocity of light, and through other non-conductors or dielectrics with a smaller velocity, precisely as in the case of the radiant energy of light or heat. Henceforth the complete equation for the distribution of energy by means of alternating currents must include a term to express the radiation from the circuit. It may indeed be found that this term represents no inconsiderable part of the energy communicated to the wire in the case of very rapid alternations.

Thus we see that the ether plays a magnificent role in what may be called its dynamic relation to electric displacements. In its capacity as a reservoir of static or potential energy its agency has been better understood for a considerable period. When a continuous current begins to flow through a closed circuit, a single wave travels out from the conductor; and during its progress, while the current is approaching its constant value, the inclosing ether is assuming its condition of static repose under stress. The whole ether, extending indefinitely outward from the conductor, is profoundly modified.

We know how to map out the circular lines of force about it by means of iron filings; but the iron serves only to show what has already taken place in the ether before the filings are brought into the field. Every little iron particle becomes a magnet, with all the north-seeking poles stretching in one direction round the wire, and all the south-seeking poles in the other. What the mechanism of the stress, or the motion in the ether to produce these effects, may be we do not know; but we do know that these lines of force are all subject to a tension tending to shorten them, and that they are mutually repellent laterally. When a current is sent through a conductor, the ether is expanded in concentric cylindrical layers about any straight portions of the circuit, and becomes the reservoir of potential energy.

As soon as the current, which maintains this state of tension, ceases to flow, the stretched ether collapses upon the conductor, yielding up its energy in the form of self-induction. If a steady current is conceived as the setting up and breaking down of a static difference of potential energy at infinitesimal intervals of time, then the energy transmitted may depend upon a similar formation and decay of the static stress in the encompassing ether. The conductor is but the core of an electro-magnetic disturbance in the surrounding medium; and it may be that the enormous energy which a small copper wire can apparently convey is in reality transmitted by the invisible medium.

From this brief review of the theory of electric action it will be quite evident that henceforth the language applied to electrical phenomena must always include the luminiferous ether as a prominent term. The experiments of Hertz have made it impossible to explain electrical facts without taking this invisible medium into account. There is no such thing as electric or magnetic action at a distance. The ether is always an essential part of that complex system the interactions of which manifest themselves as electric or magnetic phenomena.

As the ear responds to the slow oscillations of an electric discharge through the intermediate agency of heat, so the eye of the mind responds to those more rapid oscillations, the existence of which has been demonstrated by experiment. No less clearly does the magnetic field appear as a system of lines of stress in the ambient ether. Definiteness has taken the place of the metaphysical speculations of earlier times. Complete ignorance has, at least, been superseded by half knowledge. We may not yet affirm with Edlund that the ether *is* electricity, but we are doubtless nearer a solution of this old problem than ever before.

"The discord is vanishing slowly,
And melts in the dominant tone;
And they that have heard it can never
Return to confusion again,
Their voices are music forever,
And join in the mystical strain."

ELECTRIC MOTORS.

MR. F. L. POPE, the well-known electrical engineer of this city, contributed the following interesting statements to a recent number of the *Journal of Commerce*:

One of the ablest modern writers on industrial questions lays down the proposition that the limitations of the advantages derived from the use of any form of force for industrial purposes are fixed by the possibility of distributing the power cheaply and economically, and, furthermore, that of the two factors, the power to distribute cheaply is of far greater importance than the power to produce cheaply. In illustration of this proposition, consider the cheapest source of energy now known, namely, the power of falling water. It has not been found possible to effect the distribution of this form of power except over very limited areas, from which it follows that all the industrial benefits derived from water power have necessarily been concentrated in the immediate vicinity of the point of its origin, and hence, when such places have been conveniently situated in other respects, they have acquired great industrial and commercial importance. Such instances may be found at Lowell, Lawrence, Manchester, Fall River, Holyoke, etc.

On the other hand, there are instances of very extensive and valuable water powers which cannot commercially be utilized, by reason of their geographical or topographical situation; such, for example, as the water power at Falls Village, Conn., one of the finest in New England, which is practically unavailable because there is not level ground enough in the vicinity to afford sites for the necessary factory buildings, tenements, and adjuncts.

Scattered all over New England, and, in fact, most of the Atlantic States, are innumerable mill sites of from 50 to 1,000 horse power, many of which were improved in former days, but which are now lying idle and contributing nothing to the industrial wealth of the community, by reason of their remoteness from modern facilities of transportation and other inconveniences of their situation. Every horse power of energy thus running to waste would be worth to the community from $50 to $100 per year, were it so situated as to be utilized to the best advantage.

It is manifestly an important part of the mission of modern electrical development to render all this waste power once more available for industrial purposes. Every increase in the limits of the economical distribution of power increases the opportunity for employment, adds to the ease, convenience, and comfort with which the artisan accomplishes his work, and enlarges the surplus wealth for the community.

The two countries which have made by far the greatest advances in the utilization and distribution of electric power are Switzerland and the United States. It is well known that Switzerland is disadvantageously situated as a manufacturing country, for the reason that, although it is supplied with an almost unlimited number of the finest water powers in the world, situated upon unfailing streams fed by the melting of Alpine snows, yet these are located, in almost every instance, in inaccessible valleys and ravines, where economical transportation of heavy products is impossible. The railroad lines are situated in the main valleys at too great a distance from the water powers, in the majority of cases, to render them of much value. Steam power, on the other hand, is expensive, as there are no coal mines in the republic, and the coal used must be brought many hundred miles and up heavy grades, which render it so costly that the Swiss manufacturers have been unable to compete successfully with those more favorably situated in countries in closer proximity to the iron and coal districts. The manufacturers of Switzerland have, for this reason, heretofore been confined to the lighter and more delicate varieties of machinery, in which the cost of labor is the principal element, and the cost of transportation an inconsiderable one.

The recent introduction of methods of transportation and distributing power by electricity is rapidly changing this state of affairs, and in a few years it is probable that Switzerland will become one of the foremost manufacturing countries of Europe in all those varieties of industry in which cheap power is an important element, such as the manufacture of steam engines, locomotives and heavy machinery, of paper, cotton and woolen goods, and the like.

In the ancient city of Solothurn, in the northwestern part of Switzerland, there is a manufactory of machine screws which is driven by an electric motor of 50 horse power, which derives its energy from a turbine wheel which is situated on a mountain stream at a distance of over five miles from the works. The electric current is conveyed upon wires not larger than an ordinary lead pencil, suspended upon poles on the public highway. No one would notice any difference between this line and the ordinary telegraph line; and, in fact, there is no difference except that the construction is rather more substantial and the insulation more carefully attended to.

The proprietor of the factory informed Mr. Pope that his electric motor had been running eleven hours a day for over two years, and had never been out of order for a moment, and had required no repairs; he could not say too much in its praise.

The gentleman also visited a delaine mill at Derendingen, Switzerland, of 36,000 spindles and the necessary complement of other machinery. The factory was driven by a pair of electric motors of 250 horse power, deriving their energy from a turbine wheel situated about twelve miles from the factory, the connection being made by a line of insulated copper wire similar to the one at Solothurn. The manager of this factory told exactly the same story. He had never had any trouble whatever with the motors, that had been running for a year without repairs, and appeared likely to run for an indefinite length of time. He considered it far superior to any other form of power, especially in the manufacture of the delicate white woolen goods, in which the absence of smoke, cinders, and dirt from a steam engine was a particularly desirable condition. This is also the case in paper making and other industries of like character.

The cost of this electric installation at Derendingen, including the electric generators, electric motors, and connecting conductors, was about $15,000 of our money, or about $54 per effective horse power. The cost of attendants, repairs, and maintenance is trifling.

There are several other instances of electric power transmission in Switzerland. One of these, at Lucerne, carries 120 horse power half a mile, and another 250 horse power a quarter of a mile.

From what Mr. Pope saw, it was quite clear that there could be no possible difficulty in conveying even 1,000 horse power at least a distance of five miles, and there is no reason to suppose that this distance is anywhere near the possible limit which may be attained.

The installations described were put in by the Oerlikon Machine Co., whose works are near Zurich, and employ about 800 men. The visitor was informed that, in consequence of the success of the plants at Solothurn and elsewhere, their books were crowded with orders, and especially that they had received an order from Northern Italy for a much larger plant than any which had yet been erected.

We have no examples in the United States of anything like this amount of power being transmitted and utilized by a single motor. The writer says he does not know of any motor which has yet been set up of over 60 horse power. The development of power transmission in the United States has been mainly in the direction of distribution from a common source of energy to many small motors. Recent returns afford a basis for an approximate estimate that there are as many as 6,000 electric motors to-day in use in the United States for industrial purposes. These have a capacity varying from the small one-sixteenth horse power which is used to drive a family sewing machine up to the 50 and 60 horse power motors employed in mining and milling works.

One of the most common and favorite sizes is 10 horse power, of which large numbers are in use in New York, Boston, Baltimore, Rochester, and many other places.

Every manufactory of electric motors in the United States is crowded to its utmost capacity in its efforts to meet the constantly increasing demands for electric power. Mr. Pope thinks it is apparently only a question of time, and not a very long time either, when it will be difficult to find in any city a steam engine of less than 50 horse power capacity, the demand for smaller motors being met so much more conveniently and economically by the electric motor.

THE STRIKING OF THE EIFFEL TOWER BY LIGHTNING.*

By M. MASCART.

SEVERAL of my colleagues have thought that it would be interesting to give a few details relating to the striking of the Eiffel tower on the evening of the 19th August last, an event which has been the subject of several exaggerated accounts. I have taken these details from the report drawn up by M. Foussat, chief of the electrical service, who was on the upper platform during the storm.

The tower is provided with a central rod projecting from the summit, and with eight oblique rods situated on the balustrade of the third platform. The bronze point tipped with platinum, which was originally at the end of the central rod, had been taken off a few weeks previously on account of its shaky condition.

At 9:40 P. M. the principal lightning conductor at the summit was struck, with a noise like that of two small cannons. Some red drops, due probably to the combustion in the air of volatilized iron, fell from the point, and it was subsequently found that the screw at the tip of the conductor was so scored that it was necessary to file it before the set of points could be replaced. A glow, accompanied by considerable crackling, was noticed several times on the rods attached to the platform. The lighthouse keeper was attending to his apparatus, two men were working the projectors on the platform, and M. Fousset was leaning against the handrail watching the rod attached to the lighthouse.

It is worthy of notice that none of these four persons felt the slightest shock at the moment when the flash struck the conductor. However, on account of the heavy rain and the possibility of danger if a second flash struck the tower, the projectors were extinguished and the three persons on the platform sought shelter

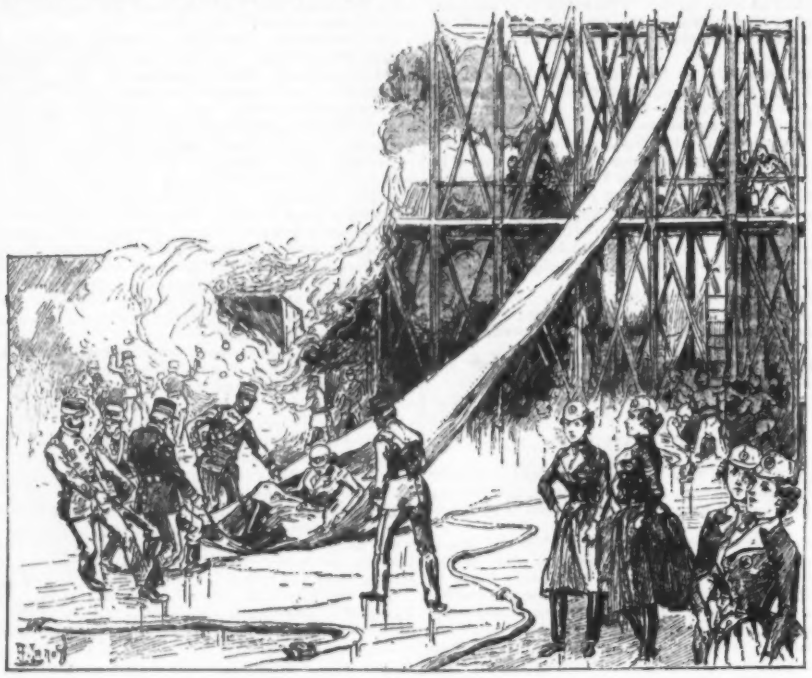
* *Comptes Rendus*, vol. cix., No. 9.

in the laboratory. At this moment a highly electrified cloud descended on the top of the tower. It was this doubtless which gave many people in Paris the idea that the top of the tower after the flashes seemed to be enveloped in an electric glow of such intensity that it completely eclipsed the light of the projectors. I should add that the meteorological instruments at the bottom of the conductor experienced no injury whatsoever. This flash was, in short, in conformity with all known facts, and showed moreover that the earth connection was perfect and the tower absolutely safe.

INTERNATIONAL CONVENTION OF FIREMEN AT PARIS.

THE firemen have had their week of triumph, they having held at Paris an international convention, which was succeeded by a competitory trial of apparatus that was witnessed by an immense crowd of spectators. The Parisian, ever a jester, asked himself whether it was necessary to make merry over the arrival of so large a number of firemen—those good fellows who have been so much satirized in song and abused in caricature.

But when the Parisian witnessed the advent of those large red trucks, those long ladders, all that apparatus that is never met without fright in the streets, on the occasion of a fire, he no longer thought of anything but those modest heroes in the ranks whose nobly performed duty has already made so many victims. He called to mind all those obscure but courageous fellows whose names at morning roll call have been answered to, in a grave voice, with the words: "Killed at a fire." Killed at a fire; thus it was with Lieut.-Col. Froideraux, whose glorious end was announced in unusually high terms by Col. Couston to his picked regiment. Killed at a fire; so, too, with many others whose obscurer names would be worthy of surviving so glorious an end. Let us, then, if our heart bids us to, laugh a little at these brave men, who do not, all of them, wear the plume, whose countenances are sometimes more simple than martial, and who, after the fatigues of a review, do not hesitate to bare their breasts, or to have their machine, which has never before been present at such a fete, hauled behind a carriage in which they ride with affected dignity. But let us not forget the fine and great things in remembrance of which Paris was desirous of handsomely entertaining the firemen. These latter came in numbers from the various districts of France and from foreign countries. The most varied uniforms were intermingled in this reunion of braves. English, Portuguese, Luxemburgers, Hungarians, Italians, Russians, and even Americans, had assembled in order to study at the convention the best methods of saving life. The competition took place upon the magnificent race course grounds of Vincennes, and was opened in the presence of the president of the republic. All the companies vied with each other in skill, and the English brigades, led by Major Heath and Capt. Davies, performed some most curious experiments with chemical fire extinguishers. A section of young women



TUBULAR FIRE ESCAPE AT THE PARIS EXHIBITION.

—firewomen, as they are called in England—who came under the escort of a pretty female sergeant, took part in the exercises. They went through their maneuvers with very noticeable skill and agility, and, in every case, demonstrated that certain life-saving apparatus can very well be put into the hands of women, and that it would prove expedient to make the employment of the latter more widespread.

Very curious, too, is the method of saving lives by means of a long bag, whose mouth is fixed to a window, and which, placed at a proper inclination, receives the persons to be rescued. These latter slide down in succession through the canvas tube thus formed, and reach *terra firma* without danger and with incredible rapidity.

The regiment of firemen of Paris, debarred from competition, received a very beautiful Sevres vase offered by Mr. Carnot.

The final review was made at Neuilly by Col. Ruyssen, the commander of the Paris firemen. Gen. Henrion-Berthier, mayor of Neuilly, was present, and, after the procession was over, offered a lunch to the French and foreign officers, who all drank to the union of the peoples represented at the convention and at the firemen's competition.—*L'Illustration.*

A GLANCE AT THE FRENCH EXHIBITION.

A CORRESPONDENT of the *Chemist and Druggist* says: The dominating feature of the exhibition is, of course, the Eiffel tower, which has been so often described and figured that every one by this time must be familiar with its form and dimensions. Suffice it, therefore, to say that the best time to ascend the tower is between ten and twelve in the morning on a week day, before the daily stream of sightseers has properly set in. In the ascent, if the third platform be the visitor's objective, as little time as possible should be spent in looking at the panorama presented from the first and second platforms, because the traveler, if he tarries on either of these, may probably find a *queue* of from two hundred to three hundred persons waiting their turn to take tickets for the succeeding platforms. At the end of that *queue* he will have to go, willy-nilly, patiently waiting his turn, any attempt to push his way to the front in British fashion being sure to bring confusion upon him. The first platform is at an altitude of 57·63 meters (202 feet) above the ground, slightly less than the towers of Notre Dame, and an idea of its size may be obtained from the fact that the four restaurants which are situated on it can together accommodate about 2,400 people, leaving room for nearly twice as many more to walk about comfortably on the platform. At the second platform you are nearly on a level with the gilded dome of the Hotel des Invalides, the elevation being 115·73 meters, or 386 feet. There is room for 1,500 people here, and at the printing office of the *Figaro* on this platform they will give you as a memento a specially stamped copy of the paper, recording the fact that you, "le sieur X.," have ascended the second platform on such and such a date. From the second to the third platform visitors are taken up in batches of fifty, that being the number the lift will accommodate. The exact height on which you are standing there is 276·13 meters, or 920½ feet. There is room for about 800 mortals besides yourself, and, armed with one of the field glasses which you can hire for a franc on the first platform, you may, on a clear day, see Evreux and Chartres in the west, Pithiviers and the French saffron country in the south, Soissons and Chateau-Thierry in the east, the radius of your field of vision being ninety kilometers, or about fifty-five miles. The area thus covered comprises nearly one-sixteenth part of France, and would equal, supposing the Eiffel tower to be situated at Westminster, a view from Margate in the east to Salisbury in the west, Chichester in the south, and Bedford in the north. The tower has cost 260,000*l.* ($1,300,000) and the city of Paris has given free of cost the site upon which it is built, while M. Eiffel has received a subvention of $300,000 from the state, to which, after a period of twenty years, the Eiffel company has to cede the ownership of the tower without compensation, vested interests being at a discount in modern France. It is asserted that the tower will be of considerable scientific utility, and time will doubtless show the truth or otherwise of that statement; so far the only scientific "discovery" in connection with the tower has been the unsupported statement by a French savant claiming the fallacy of Kirchhoff's spectrum theories.

While the tower was being built, a number of eminent French artists and *litterateurs* published a protest against its construction, their objections being of an æsthetic character. Now the edifice is completed, Parisians have become rather proud of it, and we think justly so, but it cannot be gainsaid that its vastness detracts from the imposing nature of the exhibition monuments around it, especially the sculptured fountains and the main building. As regards the latter, the central dome is undoubtedly its grandest feature, and we should judge it to be the most beautiful thing in the whole of the exhibition. Its shape and coloration simply beggar description, and the warm orange and red copper tints which prevail in it form an agreeable contrast to the rather too vivid blue of the other parts of the buildings. The two great side galleries, as already stated, are devoted, the one to the right of the Eiffel tower to the liberal arts, and the left one to the fine arts, the latter containing a remarkably fine collection of pictures, including a goodly number by Russian, Austrian, and German artists, and a large collection of sculptures, many of which are familiar to

ENGLISH FIREWOMEN AT THE PARIS EXHIBITION.

CAPTAIN DAVIES AND A GROUP OF ENGLISH FIREMEN AT THE PARIS EXHIBITION.

frequenters of last year's Italian exhibition in London. The central part of the main building is devoted to French exhibits only, the other European countries, together with the States, the English and Dutch colonies, Japan, Siam, Egypt, and Persia being lodged in the wings. The machinery gallery, stretching the whole of the width of the exhibition at the back of the Central Palace, is also almost exclusively French, Great Britain, the States, Belgium, and Switzerland together occupying about one-twelfth of its space. Each Latin-American state has a pavilion of its own in the grounds, the handsomest being those of the Argentine Republic and of Mexico, the latter representing an Aztec palace, such as may have been the home of Montezuma when Cortez with his warriors invaded the ancient kingdom. On the right side of the main building there is one court which will especially attract the visitor by the richness of its decoration, coupled with an entire absence of glaring ostentation. That is the French perfumery section, class 28 of the third of the nine "groups" in which the exhibition is divided, that of "furniture and its accessories." There are 138 different stalls in this court, each one representing a French firm, and in addition to this quite a number of exhibitors of "matieres premieres," raw materials for perfumery, have stalls in the French colonies. Algeria and the little island of Reunion, for instance, contribute twelve exhibits each. The interest of this section, when we consider the long association of France with the industry, merits a full description of its contents, and this we shall give in our next article.

THE JOURNALS OF THE WORLD.

AMONG the numerous statistics on view at the exposition, there is one that engaged our attention, and that is regarding the total number of journals which appear in the whole world.

This demonstrates, in the first place, that France does not publish the largest number of periodicals in Europe. That honor belongs to Germany, which publishes 5,500 periodicals, of which 800 are dailies. The journals devoted to religious dogmas, creeds, and scientific theories abound. The oldest German journal is the *Gazette des Postes*, of Frankfort, founded in 1616; the most widely circulated, the *Berliner Tagenblatt*, issues but 55,000 copies.

After Germany comes England, which publishes 3,000 periodicals, 809 of which are dailies. France follows with a nearly equal number, which, officially, is 2,819, of which only a quarter are dailies and biweeklies or triweeklies.

Italy holds the fourth rank, in publishing 1,400 journals, 200 of which appear at Rome, 140 at Milan, 120 at Naples, 94 at Turin, and 79 at Florence. Of these periodicals, 170 are dailies. The oldest is the *Gazette de Genes*, established in 1797.

In Austria-Hungary there are 1,200 journals, of which 150 are dailies.

Of the 830 papers published in Spain, one-third are periodical. The first specimens of the Spanish gazettes, formerly called *relaciones*, were peddled about by the blind. They appeared at indifferent epochs, and often assumed the form of romances.

Russia publishes but 800 journals, 200 of which appear at St. Petersburg, and 75 at Moscow. An infinite number of languages are represented in the Russian press.

In Greece, journals are proportionally numerous. Every little market town has one. Athens publishes 54, all of them dailies.

In Switzerland, there are 450 journals published, and Belgium and Holland furnish nearly an equal number of publications.

In Sweden, Norway, and Portugal journalism is but little cultivated.

In Turkey the journalistic movement is quite active.

Upon the whole, Europe possesses 20,000 journals.

In Asia, we find no less than 3,000 periodical publications. Most of them appear in Japan and the English Indies.

China is not so well supplied, having but the *King-Pau* (the official journal of Pekin, which issues three editions a day on paper of different colors), and one journal at Shanghai and another in Corea. The advent of this latter paper caused a grave discussion. The question was ,to know in what idiom it should be printed. Chinese was first tried, but, as objections were made, it is now printed in Chinese and Corean.

Japan publishes 1,500 journals. Among these, we may mention the *Hotchishimboun*, the *Nitchinitchishimboun*, the *Tchoyashimboun*, and the *Mainitchishimboun*. The latter is the organ of the Japanese radical party.

There are three French journals, one in Cochin China, one in the Indies, and one (the recently established *Avenir*) in Tonkin.

In Beloochistan and Afghanistan there are no journals, but, as an offset, there are six in Persia.

As regards the press, Africa is disinherited. It possesses but 200 journals, 30 of which are published in Egypt, and the rest in the European colonies.

As might be supposed, America comes in for a large share. In the United States alone there are 12,500 journals, 1,000 of which are dailies. The first American journal appeared at Boston in 1704, under the name of the *Boston News*. Although but slightly developed up to 1800, an epoch at which there were but 200 journals, the press of the United States has made remarkable progress since the beginning of this century. In fact, in 1840 there were 1,630 journals enumerated, and in 1860 the number was 4,000. It will be seen that, since then, the figures have been more than trebled.

In Canada there are 700 journals, most of them in French. Aside from Mexico and Brazil, in which quite a large number of journals are published, it only remains to cite the Argentine Republic, the press of which is represented by 60 publications.

As a last detail regarding journals in America, we may state that there are in the United States 120 journals edited and published by negroes. The oldest of such papers is the *Elevator*, which was established at San Francisco eighteen years ago.

There are but four journals to be found in Oceanica, and these are edited by the European colonists. We need only mention Australia, in which there are 700 papers, all in English, and the Sandwich Islands, whose capital, Honolulu, publishes 8 journals—5 in English and 3 in Hawaiian.

Being given the population of the globe, it has been calculated that there exists one journal for every 82,600 individuals.—*La Nature.*

SARAH HEATH, CENTENARIAN.

THE photograph accompanying this paragraph is that of Mrs. Sarah Heath, who now lives in the northern part of Somerset County, N. J., near the village of Peapack.

SARAH HEATH, CENTENARIAN.

It was taken on her one hundredth birthday, which occurred on the 24th of July, 1889, and presents to us a remarkably well-preserved old lady.

Mrs. Heath was born about two and one-half miles from the town of Flemington, N. J., on the South Branch River. Her father was William Cool, and her mother's maiden name Sarah Post. She has resided all her life in Hunterdon and Somerset Counties, the most of the time in the latter county. When about twenty years of age she married Robert Heath, who was only a few months her senior, but whom she survives about twenty years. Mrs. Heath has been the mother of four children, two sons and two daughters. But one of these, however, is now living, her son William, a stalwart youth of 73 summers. There are now living besides him five grandchildren and sixteen great-grandchildren of her immediate family.

There are some interesting facts concerning this dear old lady that, considering her advanced years, are quite remarkable. One is, that she has not missed her seat at the table during the past five years.

She has been blind for two or three years, but, with the aid of crutches, goes unaided from the sitting room to the dining room. About two years ago she had her mouth refitted with a new set of artificial teeth, as if she expected to live some years longer, and to look at her one would think she might easily last still another decade. Her mental faculties are wonderfully bright and well preserved. When her friends came to greet her on her one hundredth birthday, she received them with remarkable vigor, and eagerly inquired about the members of the family. Her memory of persons, events, and places is especially strong and vivid, and her personal reminiscences of great interest. Her mental brightness was displayed in an amusing way. Her old pastor, Dr. Rankin, of Basking Ridge, N. J., was present. In the course of some remarks he was impressing upon those present the advantages of a quiet and sober life. He appealed to her for confirmation of his remarks, to which she replied in a sprightly manner: "Some people are of no use to themselves or anybody else, and they might as well be out of the world as to live any longer."

Her father was a patriot. She remembers how he was wont to tell of his going with loads of provisions to supply the needs of the revolutionary soldiers. She also repeated portions of a patriotic song that was sung during her early days. It may be familiar to some of our readers. We give one stanza of it:

> "Great Washington, he was the one
> That led the sons of freedom on;
> He fought our foes on every side,
> And boldly humbled Britain's pride."

Some idea of her years may be obtained when we stop to think that she has lived under every presidential administration this country has yet seen. Truly we are but a young nation, if one life can span our national history.

THE BARCELONA CAPTIVE BALLOON.

THE history of ballooning records of late years nothing of greater note than the achievements of Henri Giffard, who, during the exposition at Paris in 1878, constructed a balloon with a capacity of 25,000 cubic meters, and operated by a 200 horse power steam engine.

Since then a number of balloons have been built on a smaller scale for carrying a limited number of passengers to a certain elevation. The balloon shown in the accompanying illustration was constructed by Mr. Gabriel Yon, who, during the past few years, has become well known as the inventor of a new material for military ballooning.

The captive balloon at Barcelona has a capacity of 42,000 cubic meters. It is made of a single piece of pongee silk, having a resistance of 1,000 kilogrammes per square meter.

Pongee silk is an important factor in the construction of a balloon, as it is light, solid, and comparatively inexpensive, only costing about three francs per square yard. It is strong enough for a balloon of 4,000 or 5,000 cubic meters capacity. For a balloon, however, the size of the Giffard balloon there should be double thickness of silk coated with rubber.

THE BARCELONA CAPTIVE BALLOON.

The balloon should be provided with an annular compartment proportional to its size, and this compartment should be filled with air to retain the special shape of the balloon when the coldness of the upper atmosphere is reached. The basket is circular, like that of the Giffard balloon. There is an opening in the center for the passage of a cable, to which is connected the dynamometer indexed to 3,000 kilogrammes. The cable is 400 meters in length, and has a tensile strength of 10,500 kilogrammes.

The balloon is controlled by a 25 horse power engine, which operates a winding drum which will carry 400 meters of cable, with a division on its border for the electric wires. The cable passes over a pulley which is mounted in the center of the inclosure.

The first balloon constructed at the shops at the Champs de Mars was in active use at Barcelona from June 4 to June 25, 1888, when it was struck by lightning and burned.

After this accident Messrs. Yon and Louis Godard received an order for a new balloon of 4,200 cubic meters capacity. This was begun on July 5, 1888, and made an ascent at Barcelona on August 11. It was in use for thirty-seven days, when it was emptied on September 17 for revarnishing. It was inflated a second time on September 19.

The ascensions took place regularly from that date until January 23, 1889; *i. e.*, for a period of 125 consecutive days. This continuous use has never been surpassed by any balloon. These experiments are to be tried again at Madrid.

One thousand seven hundred and forty-two ascensions were made under the management of the aeronauts Eugene Taupin and Eugene Godard, Jr. Twenty thousand nine hundred and four passengers were carried, or twelve each trip. The entire length of time that the balloon was in use was nearly six months.

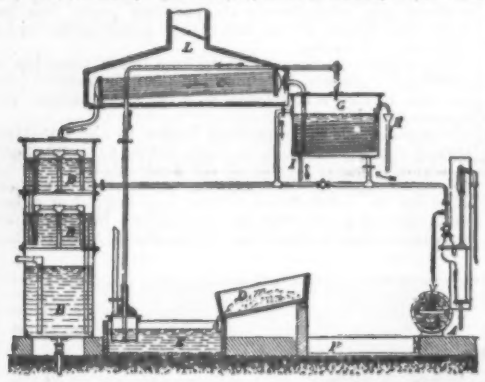
The Barcelona balloon was inflated with illuminating gas. The loss in 24 hours was about 214 cubic meters, or about 5 for every 100.

This enterprise proved to be thoroughly practical, very interesting, and very popular with the public.—*Gaston Tissandier, in La Nature.*

THE CONCENTRATION OF AMMONIACAL LIQUOR.

In view of certain inquiries, we give an illustration, reduced from the plate in the *Compte Rendu* of the Societe Technique, showing M. Chevalet's arrangement, with a short description obtained from the same source.

It will be seen that the appliance consists essentially of a saturator, G, a still, B, and a cooler, C (the last



named being placed in an exhaust chimney, L). The crude liquor enters at A, and is pumped into the saturator, whence it issues by an overflow pipe, and passes into the still, where it parts with all its carbonate and hydro-sulphate of ammonia. From the still it passes into a boiler heated by a naked fire, where it is submitted to the action of milk of lime, which decomposes the fixed ammoniacal salts. When the liquor in the condenser becomes too hot, it is cooled by a stream of water admitted by the pipe, I, and, traversing the worm pipe, passing out at H. As soon as the liquor from the saturator is sufficiently concentrated, it is drawn off into a cask, K, made of either wood or sheet iron; the latter material being preferred, for the reason that if any crystallization takes place, the crystals can easily be dissolved, and the liquor recovered, by plunging the cask into a tank or reservoir of hot water. The gases or vapors given off during the process are led into a small acid trough, E, which retains whatever ammonia may have passed from the saturator, or into a small scrubber supplied with a spray of cold water. D is the drainer, and F the sulphate drying floor. With regard to the uncondensable gases, which consist principally of carbonic and hydro-sulphuric acid, they are conveyed under the boiler furnace, so that they may be burnt and their disagreeable odor destroyed.

The concentrated liquor is of 18° to 20° Baume, or from 1·134 to 1·152 specific gravity; but instead of containing only about 14 or 15 per cent. of ammonia, as in the case of ordinary concentrated liquor, it contains from 25 to 26 per cent., or about as much as the dry sulphate. The product is liquid in spring; but in winter it crystallizes in the receptacles in which it is stored. By drawing off the mother liquor, a product showing on analysis from 27 to 28 per cent. of ammonia is obtained. It is therefore in this respect equal in value to sulphate, and, of course, it is liable to the same expenses of carriage. But it possesses this advantage over the salt, that it can be produced wherever there is ammoniacal liquor to be treated. It has this drawback, however, as compared with sulphate, that thoroughly sound casks are necessary for its transport, and consequently the cost of carriage is augmented by reason of the additional weight. It may be asked how it happens that this product, while equal in density to those obtained by other appliances now in use, contains a higher percentage of ammonia. It is simply because it has in its composition less carbonic and hydro-sulphuric acid than is to be found in the other products; and, furthermore, it contains 13·8 grammes (about 213 grains) of ammonia per degree Baume per liter (0·22 gallon).

The advantage of this system of concentration may be said to be, in the first place, that it yields a marketable product; secondly, that it reduces 220 gallons of liquor of 1·03 specific gravity to rather more than 15 gallons of 1·152 specific gravity, or to about 1-15th of its former bulk. Therefore, in the case of works carbonizing 1,000 tons of coal, there would be produced, by good washing in a well-fitted scrubber, about 22,000 gallons of liquor, which by concentration to 1·152 specific gravity would be reduced to about 1,520 gallons. These results should merit the attention of those managers who experience any difficulty in disposing of their ammoniacal liquor.—*Journal of Gas Lighting.*

RAPID FILTRATION.

By Reginald A. Fessenden, Chemist, Edison Laboratory, Orange, N. J.

The use of filter pumps, as every chemist is aware, does not, in a very great number of cases, facilitate filtration: first, because a dense layer of the precipitate forms next the paper, which continually requires to be removed, and second, if any considerable pressure is used, particles of the precipitate will pass through.

Fig. 1.

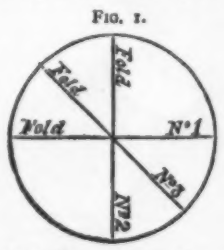
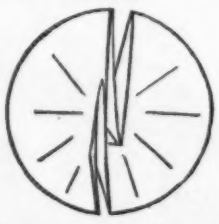


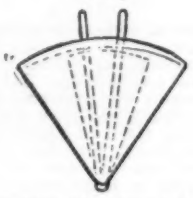
Fig. 2.



To increase the surface seems to be the better plan. Plaited filters partially effect this, but the precipitate cannot be easily detached from them, and they are troublesome to prepare. Ribbed funnels, while also an improvement, have only one side of the filter for use, the other side being covered with three thicknesses of filter paper.

Fig. 3.

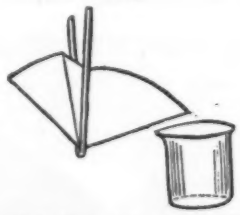
Fig. 4.



The following method enables filtrations to be made very rapidly, and in such a manner that the precipitate can be readily removed:

The filter paper is folded three times; folds Nos. 1 and 2 are toward the reader, No. 3 from him. The filter is then gathered (Fig. 2), and a piece of glass rod, bent at a very acute angle, inserted in the cleft of the

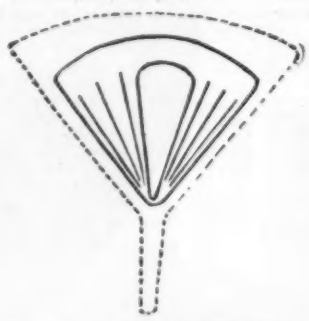
Fig. 5.



filter (Figs. 3 and 4), thus giving a filtration surface of nearly four times the usual one.

The filtration being complete, the glass rod is grasped by the projecting ends and lifted from the funnel, bearing the filter upon it. One end of the filter paper is then bent down, and the precipitate is easily washed off (Fig. 5).

Fig. 6.



An improvement on this is to use, instead of the glass rod, a plate of glass (Fig. 6) ribbed on both sides. This renders the filtration very rapid indeed, and if it were made by the manufacturers of chemical apparatus, would no doubt be used.—*Chem. News.*

PURE CHLOROPHYL.

It has long been known that the ordinary green coloring matter of leaves is a mixture of two substances, chlorophyl green and chlorophyl yellow, in varying proportions. Professor A. Hansen claimed some time ago to have separated pure chlorophyl green; but Dr. A. Tschirch maintained that Hansen's substance was a compound of chlorophyl and sodium. Dr. Hansen now concedes this, but believes that he has more recently succeeded in separating pure chlorophyl green by the following process.

Grass leaves were boiled in water for from a quarter to half an hour, then washed in water, pressed, and dried in the dark. The chlorophyl pigment was then extracted with boiling alcohol, and the solution saponified by heating for three hours with a slight excess of caustic sodium. The excess of sodium was then converted into carbonate by carbonic acid, and the mixture thus obtained dried in a water bath. The chlorophyl yellow was then extracted with ether, in which the compound of chlorophyl green with sodium is quite insoluble, and then with a mixture of equal parts of alcohol and ether, in which it is only slightly soluble, and the residue extracted again with a mixture of equal parts of alcohol and ether and phosphoric acid. This sets free the chlorophyl, which dissolves in the mixture of alcohol and ether, and can be evaporated as a shining black green perfectly solid brittle substance, insoluble in water, benzol, and carbon bisulphide, soluble with difficulty in pure ether, easily in alcohol. The solution has a beautiful pure green color, which becomes red and strongly fluorescent when concentrated. It offers great resistance to reagents, especially mineral acids. Its exact composition has not been ascertained, but it contains iron and nitrogen.

Pure chlorophyl yellow can also be obtained by a different process from grass leaves. It crystallizes in orange red crystals insoluble in water, but soluble in alcohol, ether, chloroform, and benzol, with a dark yellow, in carbon bisulphide with a red color. Dr. Hansen states further that the yellow coloring matter of flowers and fruits, and that contained in the petals of the poppy, is identical with the chlorophyl yellow of leaves. As regards the mode in which chlorophyl occurs in the living cell, the green substance which fills up the vacuoles of the chlorophyl grains is not a solution, but consists of combinations of the two chlorophyl pigments with fatty acids which possess a half-solid consistence.

In a recent publication Dr. Hansen gives a detailed account of the observations on which the above conclusions are founded, and a very useful *resume* of the literature of chlorophyl.

OUR SENSATIONS OF MOTION.*

We may distinguish two quite different kinds of sensation of motion, active and passive. When we walk, or run, or row, we use our muscles, and this use of our muscles is the cause of our motion, and also the cause of special sensations which may in a sense be called active sensations of motion. But we have other sensations than these connected with motion. For, if we are carried, or rocked in a boat, or dropped from a height, we are not only moved, but we are conscious of a very well marked sensation which we may call a passive sensation of motion. When we move ourselves we feel both kinds, and it is difficult for us to analyze what we feel, and distinguish between our sensations as movers and our sensations as moved. It is to our passive sensations of motion that I wish to direct your attention tonight, and as these can best be examined in cases where they are not complicated with the other kind, we shall confine our attention almost exclusively to passive motion, that is, to cases where we are moved without any exertion of our own muscles. Now the first thing I have to say is in at all events apparent contradiction to the title of this lecture. It is that we have no direct sensation of motion as such. That this is so will be at once obvious if we consider the fact, known to all, that we are at this moment being moved with very great velocity through space. We know that this is so, astronomers can prove it, but we are so perfectly unconscious of it that I dare say most of us here could not point the direction in which we are moving; in fact, as we are ignorant of the direction and rate of motion of the great system of which our solar system is a part, no one can say how fast and toward what point in space we are traveling. What we are conscious of is change of motion. It is because the motion of the earth is so steady, because, although very rapid, its changes are very slow, that we do not feel it.

There are two altogether different ways in which a body can be moved. These have been called respectively translatory and rotational. In translatory motion the body is always similarly oriented. Thus, if we consider motion within so small a part of the earth's surface that we may neglect the earth's curvature, such an object as this desk is subjected to purely translatory motion if we move it thus, so that the same side always looks up, and the same side always looks east. Rotational motion involves a change of orientation and is rotation about an axis. This axis may always be the same, or it may change, and the change of axis may be abrupt or may be continuous. Most of the motions which we observe are made up of both kinds. When we travel by rail—always supposing that we sit still in the carriage—we are subjected to a purely translatory motion only when the train is running along a perfectly straight piece of the line. When it goes round a curve, we are—always supposing we sit still—subjected to rotation as well as to translation; because our face no longer continues to look in the same direction, but, as long as the train is running on the curve, continuously changes the direction in which it looks.

Let us examine what we feel when we are passively subjected to purely translatory motion. As long as the motion is steady, unchanged in speed or in direction, we feel nothing, as has been pointed out already. Let us look at the case when the speed changes, the direction remaining the same. We have to consider separately three different directions: (1) horizontal, (2) up, and (3) down, because we shall see that our sensations are different in these three cases. With change of speed in horizontal motion we are all familiar. The starting and the stopping of a train or of a steamer gives us ample means of studying it. We all know the jolt of a badly started train. What we feel in such a case is, mainly at all events, due to our body being jerked forward or backward, according as we are sitting with our back or our face to the engine. But if the train is carefully started, we find that our rate of motion may in a very short time be changed from nothing (relatively to the earth) to say thirty or forty miles an hour, without our feeling anything but the up and down rattle due to the slight unevenness of the rails. And the same was the case till comparatively lately with stopping. Now, however, since the

* Armitstead lecture delivered in Dundee, by Prof. A. Crum Brown.—*Nature.*

introduction of the continuous brake, a train can be so rapidly stopped—its rate of motion, that is our rate of motion when we are in it, can be so very quickly changed from say sixty miles an hour to nothing—that we do feel a strange, not altogether pleasant sensation. Experience has taught us what that sensation means, but at first it was so novel that experience was necessary to interpret it. It is not a sensation of jolt; the change, though rapid, is not abrupt. What we really feel, although it takes some amount of careful observation and some thought to see this clearly, is that the direction of the vertical, the direction in which a body falls, the direction in which our body presses, has been changed. We feel this most distinctly if we are standing when the brake is applied. We feel that if we do not take means to prevent it, we shall fall over, and we prevent this by bringing our body into the line of the new vertical. Our feeling of unsteadiness depends on our uncertainty how long the new state of matters is to last. It lasts as long as the speed is being changed at the same rate, and the deviation of the new from the real vertical depends on the rate at which the speed is being changed. Our perception of deviation from the vertical is pretty acute. Most of us can tell a line to be off the vertical when it is inclined only a few degrees to it. In ordinary cases we have extraneous help in judging. We have walls or chimneys, known to be vertical, or surfaces known to be level, with which to compare, but even when we have no assistance of this kind we are not often far wrong. It might be supposed that it is the pressure of our body on the floor or ground that gives us the idea of the vertical, but that idea still exists in cases where we can feel no such pressure. If our body is supported in water, or entirely submerged, as in diving, we still have a very distinct and fairly accurate notion of up and down, although in such cases, as our body is very nearly of the same density as water, the resultant pressure on it is small. We shall see in a little a possible explanation of our sense of the vertical. When the train in which we are traveling runs quickly round a sharp curve, we feel something very like the sensation just described. And indeed it is due to a perfectly similar cause; the apparent vertical is the direction of the resultant of the force of gravity and the centrifugal force, and is, as every engineer knows, more inclined to the real vertical as the curve is sharper and the speed of the train greater. In this case the sensation is complicated, because the motion is not one purely of translation, but, as already pointed out, is compounded of translatory and rotational motion.

Let us now look at cases of up and down motion. As we can study horizontal motion in the railway train, so we can up and down motion in a lift. Here also we see that it is change of motion which we really perceive. For, once the lift is started, and is moving smoothly and uniformly, either up or down, we are quite unconscious of the motion. It is the start and the stop, or the quickening or slowing of the motion only that we feel. And the stopping of the upward motion produces exactly the same feeling as the starting of the downward motion, provided they are equally smooth and free from jerk. It is easy to see what are the physical conditions here. Just as the acceleration in a horizontal direction inclines the apparent direction of gravity, so acceleration up increases, and acceleration downward diminishes, the apparent intensity of gravity. If the lift *fell* down, unrestrained, its inmates, during the short time the experiment would last, would have no sense of the force of gravity at all. An object dropped from the hand would not fall down to the floor, because the floor itself would be falling at the very same rate as the object. And what is true in this extreme case is true also in a measure in all cases of downward acceleration. But only in cases of *acceleration*, for, however fast the lift goes down, if it moves uniformly, without change of speed, the bodies of those in it press on its floor exactly as if it were at rest. Similarly, upward acceleration increases the apparent force of gravity. The physical conditions, then, of our perception of acceleration of translatory motion in any direction are change in the apparent direction, intensity, or both, of the force of gravity. It is a strange and interesting fact that our perception of downward acceleration—that is, of diminished force of gravity—is more acute than that of acceleration upward or in a horizontal direction. We feel the starting of the lift as it goes down, and its stoppage when it has come up, much more distinctly than the start on the way up or the stop at the end of the journey down. And when we are rocked in a rolling steamer, it is the beginning of the downward move that is most perceived.

Having now discussed the phenomena of our sensations connected with translatory motion, let us examine what our experience is when we are turned round, or subjected to rotational motion. We execute such movements every minute of our waking life. But as with translational motion, so, and even more, with rotational motion, it is impossible to analyze our sensations when they are complicated with what we feel we do. And in the case of rotation a very serious complication is introduced by our seeing how we are being moved.

So that, to make a strict examination of our sensations in this matter, the observer must place himself blindfolded on the rotating apparatus, and be passively turned round. Or, as in Prof. Mach's very ingenious experiments, a small hut with translucent paper windows may be placed on the turntable for the reception of the observer. Just as we can move, or be moved, right or left, backward or forward, up or down, so we can be spun round about a fore-and-aft, a right-and-left, or an up-and-down axis, and about each of these axes either the one or the other way round. It is plain, however, that we can get simple results only in the case of rotation about a vertical axis, because otherwise a great complication would be introduced by the varying position of our body relatively to the direction of gravity. We shall see that we can get everything we require with rotation about a vertical axis. Here we find, as in the former case, that it is only change of motion that is perceived. The observer sits on a chair on the turntable, his eyes are bandaged, and an assistant gives the table a steady, uniform rotation. At first the observer feels the turning quite distinctly, but after less than a whole revolution the sensation becomes very indistinct, and, while the turning still continues at the same rate, soon disappears altogether. If the rate of turning is now increased, he feels it begin again, all that he perceives being the increase; his perception of that also soon dies away, so that in a short time he may be spinning rapidly round, while he feels completely at rest, and is only aware that he has been gently turned round a little, two or three times. But if you now stop him he feels a turning round in the opposite way to that in which he really was turning, the fancied rate of turning being, at the moment of stopping, that of the real turning which has just been stopped.

This imaginary rotation dies away, exactly as the sensation of the real rotation did. Now, *very nearly* the same thing takes place, whatever is the position in which the head is placed during the experiment, *if the head is kept rigidly in the same position during the whole of the experiment.* Let us look at a case in which the position of the head is not kept the same during the experiment. The observer sits on the table, with his head inclined to one side, so that the line from ear to ear is vertical. He is now turned uniformly round; as before, he feels the turning at first, but as the uniform turning goes on the sensation dies away. When he feels perfectly at rest, let him give the word to stop, and at the same instant raise his head into the ordinary position. He will now feel as if he were being turned about the line from ear to ear—that is, now, about a horizontal axis. If his right ear was down when he was actually being rotated, and if the turning was with the hands of a watch lying with its face up, then the imaginary rotation will be the opposite way round—he will feel as if his head were going forward and his feet back.

This sensation will last only a short time, but there is a risk in trying the experiment that the observer may try to correct this alarming overturn by throwing himself backward: if he is nervous, it may therefore be as well to have him strapped to the chair. Whatever line in the head we make vertical while the real rotation is going on—that is, whatever line in the head we make the axis of the real rotation—that line is the axis of the apparent rotation which we feel when the real rotation stops, however we may move our head at the time of the stoppage. There is a practical joke depending on this principle, which I have seen played. The subject of the joke, who ought, of course, to be a person not conversant with the laws of the sensation of motion, is asked to hold a poker upright on the floor, and, placing his forehead on the top of it, to walk three times round it, rise up, and walk across the room. His march round the poker is a rotation about the fore-and-aft axis of his head. When he rises up he feels the contrary imaginary rotation about the same axis, now, of course, horizontal, so that, if he went round with the sun, he falls to the right, and to the left if he went round the other way. In a very interesting experiment with the turntable we have a combination of real and apparent rotation. Lie down on the table, say on the left side, so that the left ear is vertically under the right ear, so making the right-and-left axis of the head the axis of rotation; let the table be turned round at a uniform rate, wait until all sensation of rotation has ceased, and then, while the uniform turning is still going on, roll yourself over on your back. You will then experience a very startling sensation. The new axis of rotation of the head is the fore-and-aft one; there was no rotation about it before, therefore you feel that real rotation, the real rotation about the old axis—right and left—has just ceased, therefore you feel the imaginary opposite rotation. The sudden occurrence of the combination of these motions, felt as real, resulting from a cause so seemingly inadequate, rolling from your side to your back, gives rise to an almost dreadful sense of insecurity.

Thus then in rotational as in translational motion it is change of motion, what is technically called acceleration, which we perceive. There are two questions which naturally arise in this connection: (1) What is the use of this sense? and (2) What is the organ of this sense, and how does it work? What is the use of it? Every one will, I am sure, admit that it must be of great use to us to have a constant knowledge of the direction of the vertical; to have, as it were, a private level of our own, which we cannot mislay. As to our sense of rotation, it is to it chiefly that we owe what we call our knowledge of the arts; it enables us, as we walk about on winding roads, or through narrow crooked streets, to retain some idea of the real directions. But the chief use, no doubt, of the sense of rotation is to enable us to control and regulate the rotatory movements of our head—movements we are constantly making as we look about us. It may be asked, in these short quick movements of the head, where is the secondary sensation of turning the other way which I described? We never experience it at all. Mach has very clearly, and with great penetration, explained how this comes about. These quick movements, our habitual movements of rotation, are so short in their duration, that during them we do not come to feel that our head is at rest. The sense of the original real rotation is still vivid when the rotation is stopped, so that the secondary sensation of an imaginary motion the other way round merely annuls the primary sensation, puts an end to it when the real rotation stops. Without such a stopper of sensation we should go on feeling the rotation for a short time after it was done.

What is the organ of this sense? There is in our head a very remarkable organ which has been for long a puzzle to physiologists, an organ which is found not only in our heads, but also in the heads of all mammals, of all birds, and of all but the very lowest fishes (and even in the very lowest fishes it occurs in a less developed form). This organ is so closely related in position to the organ of hearing, that it was long supposed to be a part of it, and we shall see what attempts were made to explain it as an organ of hearing. I shall give as short a description of it as is compatible with making it plain how it can act as the organ of the sense we have been considering. I must at the same time confess that in some points our knowledge of the matter is still imperfect, and that much has still to be done before we can explain its action as fully as we can that of the eye, for instance.

The organ in question is lodged in a bony cavity continuous with that which contains the organ of hearing, and for this reason was long, and perhaps by some is still, regarded as itself having something to do with the perception of sound. This cavity in the hardest bone in our head consists of four parts—the vestibule and the three semicircular canals. The vestibule is an irregular chamber, in man about ¼ of an inch long and ⅛ of an inch broad and deep. In its walls are five openings leading to the semicircular canals. These are tunnels in the bone having an elliptical or circular section, and opening at each end into the vestibule. The central line of each canal lies nearly in one plane, which we may call the plane of the canal. At one end of each canal there is an enlargement called the ampulla. The planes of the three canals are approximately at right angles to one another. The canals are named from their position the horizontal, the superior, and the posterior; the two latter unite at their non-ampullary ends before joining the vestibule, so that there are five and not six openings into the vestibule from the canals—three ampullary, one for each canal, and two non-ampullary, one for the horizontal and one common to the superior and the posterior canals. The plane of the horizontal canal is nearly horizontal in the ordinary position of the head in all animals, and is therefore at right angles to the mesial plane: the planes of the two other canals make nearly equal angles with the mesial plane.

In the bony labyrinth just described there is inclosed a membranous labyrinth of a generally similar form. It consists of the utricle, lodged in the vestibule, and of three membranous canals, each furnished with a membranous ampulla. The membranous labyrinth does not fit tight into its bony case. The utricle is much smaller than the vestibule, which contains, besides, the saccule, an organ connected with the cochlea; and the diameter of the membranous canals, except at the ampullæ, is much less than that of the bony canals. The membranous ampullæ, on the other hand, nearly fill the bony ampullæ. The entire cavity is thus divided into two spaces, one within, the other around, the membranous labyrinth; each is filled with a liquid, the endolymph and the perilymph. The nerves are distributed to one spot in the utricle, and to a crescent-shaped ridge near the middle of each ampulla. The nerves end in hair cells, the hairs of which project into the endolymph. The *macula acustica*, the spot in the utricle to which nerves are distributed, is covered with a gelatinous layer in which are embedded small crystals of carbonate of lime.

Every one must see that an apparatus so purpose-like in its arrangement must have a use, and this use must be one applicable to all the higher animals.

It was long supposed that it had to do with our perception of the direction from which sounds come to us. The idea is not unnatural, and is obviously derived from the nearness of the apparatus to the organ of hearing, and from the relation of its form to the three dimensions of space. No explanation has ever been given how it could serve this purpose; and we can easily show that it does not do so by experimentally showing that we have no means of ascertaining the direction from which a sound comes except by two or more simultaneous or successive observations. If a sound is heard louder in the right ear than in the left we conclude that it comes from the right, and by turning round the head we soon get a sufficient number of observations to enable us to judge of the exact direction. If a short sharp noise is made at a point equidistant from the two ears, we do *not* know the direction from which it comes unless we see what causes it.

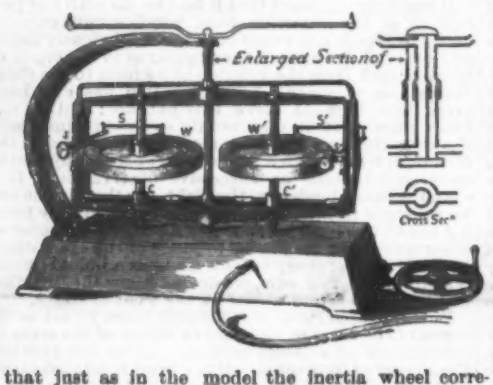
But the apparatus is admirably fitted to act as the organ of the sense of rotation, or rather of the sense of acceleration of rotatory motion. Let us first consider the action of one canal. If the head is rotated about a line at right angles to the plane of the canal, with the ampulla leading, you will see from looking at the diagram that there will be a tendency of the endolymph to go from the utricle into the ampulla, and of perilymph to go from the space between the bony and the membranous canals into the utricle.

These will conspire to stretch the membranous ampulla where the nerve endings are, and we can easily see how this will stimulate the nerves, and send a message to the brain. But this stretching will not take place if the head be rotated the other way about. In that case the tendency of the fluids will be in the opposite directions, and will rather make the ampulla less tightly stretched, and we can readily suppose that this may not stimulate the nerves, and no message will be sent to the brain. One canal will thus be able to give indications of rotation about one axis, in one of the two ways round. But for each axis we have two canals, one turned the one way and the other the other. And as by means of three rectangular axes we can represent any rotation, so any rotation will be perfectly recognized by means of the six canals. That this is actually the function of this organ is further proved by the effects of injury or disease. One ear is sometimes attacked by inflammation while the other ear is unaffected. In such cases the patient suffers from persistent vertigo—that is, sense of rotation where no real rotation occurs. This is, at least, one form of what is known as Meniere's disease, so called from the name of the physician who first drew the attention of medical men to it. Now it is obvious that, if the six canals act in the way I have indicated, the pathological irritation of the three canals of one ear will produce a sensation of rotation about an axis the position of which we can foretell from the relative positions of the planes of these three canals. And clinical observations on persons suffering from this disease show that the vertigo actually is about this axis. Deaf mutes are persons who from a very early age have had no sense of hearing at all. This condition may rise from the imperfect development of the organ of hearing, or from its early destruction by disease. In either case it often happens that the organs we have been discussing, from their nearness to the organ of hearing, are involved in the mischief, and are also imperfectly developed or destroyed by disease. Deaf mutes have therefore not unfrequently the semicircular canals in a state unfit for use. Experiments have been made on deaf mutes with the object of testing the accuracy of their sense of rotation. Those who have made these experiments report that many deaf mutes are insensitive to rotation. If these observations are confirmed, the theory I have just been explaining will receive a very great support.

In order to illustrate this theory, and to show that the principle on which it is based is a sound one, I have devised a sort of working model which I shall now show you. I may say that when I accepted your invitation to lecture here, and had selected the subject of our sensations of motion, the idea occurred to

me of making a sort of working model of the semicircular canals. The difficulty was to find an instrument maker who could help me over the obstacles which always lie in the way of a designer who is not himself an engineer. I take this opportunity of thanking Mr. Alex. Frazer for his help in this matter. He at once understood what I wanted, and so gave me the use of his skill and experience that the instrument here is exactly what I intended it to be, and a great deal better than my most sanguine hopes.

The model, as perhaps you will better see from this somewhat diagrammatic drawing than from the machine itself, consists essentially of two heavy wheels, placed side by side, with their axes parallel, in a frame which itself can be turned round about an axis parallel to that of the wheels. These heavy wheels correspond to two parallel canals, say the two horizontal canals. As it is the inertia of the fluid in the canals which enables them to work, so here it is the inertia of the heavy wheels. Each wheel has a stop, which altogether prevents its turning, in one way round, beyond a certain point. The one wheel is thus checked in turning the one way, the other in turning the other way. Each wheel is just held against its stop by a spring which is stretched when the wheel turns away from the stop. Each wheel with its stop and spring is as nearly the mirror image of the other as it could be made. When I turn round the frame, both wheels tend to lag behind the rotation of the frame, on account of their inertia. One of them cannot lag behind at all because of its stop, and the other cannot lag much behind because of its spring; the stronger we make the spring, the less can it lag behind. This lagging behind is, of course, a turning of the wheel on its axis, relatively to the frame, in the opposite sense to that in which the frame is turned. As we continue to turn the frame with uniform speed, the spring brings the wheel back to its original place against the stop, and further rotation at the same rate makes no change in the relative position of the parts of the machine. But if we now quickly bring the frame to rest, both wheels in virtue of their inertia tend to continue their rotation; one, that one which made the relative movement before, cannot continue its rotation because of its stop; the other can rotate a little, not much, because of its spring—it turns a little, but is soon brought back to its original position against its stop by the spring. You will easily see



that just as in the model the inertia wheel corresponds to the inertia of the fluid, so here the stretching of the spring corresponds to the stretching of the ampulla. All that we want to make the model complete is to find some way of making the stretching of the spring visible, something which shall correspond to the message sent to the brain. You cannot easily see the stretching of the spring while the frame is turning round, and it was necessary to devise some way of making it visible. We must here leave the analogy of the living organ. The brain turns with the labyrinth, but we are the brain of this machine, and we do not turn with it. After a good deal of consideration, and after thinking of and rejecting a good many plans, I fell upon the plan I shall now show you. In the lower end of the axle of each wheel there is fixed a stop cock, through which gas can pass from one pipe to another. When the wheel is against the stop, only a very little gas passes—just enough to prevent the jet going out. When the wheel turns away from its stop, the stop cock is opened, and the stop cock is so adjusted that the quantity of gas passing shall be roughly in proportion to the stretching of the spring. By a contrivance indicated in the diagram, the two gas pipes, one from each stop cock, are brought through the axle of the frame and led each to a gas jet.

Now, when I begin to turn the frame, one jet flares up, but as I continue the turning, as nearly uniformly as I can, you see the jets remain at their minimum, which I shall call zero of sensation. Of course I could have made this zero the zero of gas, too, but then we should have needed a subsidiary flame to light the gas when the stop cock opened. I now stop the frame, and you see the other jet flare up for a little. That corresponds to the secondary imaginary rotation which we feel when a real rotation is stopped. I ought to apologize for so often calling this a secondary or imaginary rotation. I hope you all see now that it is as really an *acceleration* in the strict meaning of the word as the original start from rest.

I have taken this question—What is the organ by means of which we perceive acceleration of *rotatory* motion?—first, because it has been most fully worked out. We now come to the question, How do we perceive acceleration of translatory motion? This, as we have seen, is the same as the question, How do we by our senses recognize the direction and estimate the intensity of what is to us at the moment the force of gravity? A very natural suggestion as to the way in which we perceive the intensity of this force is that it is a skin sensation; that it is by the greater or less pressure which we feel on that part of our body which rests on our support. Prof. Mach, to whose experiments I have had often to refer, and to whom we owe, more than to any other investigator, our knowledge of the whole subject of the sensation of motion, has very clearly proved that this is not the case. Everything we know as to this sense leads us to look for its organ in the head. And there is an organ which, to some extent, at all events, seems to be what we are in search of. The *macula acustica* in the utricle is a spot well furnished with nerves, and we have not found out any special function for it. There is a similar *macula* in the saccule, that other membranous bag contained in the vestibule. Mach has suggested that the *macula* of the utricle may be the organ by means of which we perceive acceleration of translatory motion. Let us look at it, and see how far it is fitted to act as a level. Its length is stated by Prof. Schwalbe to be about one-eighth of an inch, and its breadth a little less. According to the same observer, it covers a part of the floor, the anterior wall, and a part of the external wall of that part of the utricle called the "recess." Its nerves end, as has already been stated, in hair cells, and these are covered by a gelatinous substance filled with a fine powder of crystals of carbonate of lime. What is interesting to us in this description is that it looks in three directions, and that the whole of it is covered with a powder of considerably greater density than the fluid (the endolymph) with which the utricle is filled.

Let us try to imagine a model of this structure. Let us take a box of glass, so that we may see what goes on in the inside of it. Let us put on a part of the bottom of the box, on the end of it, and on a part of the side of it, a layer of thin jelly mixed with fine sand. Fill up the box with water, and put on a lid. We shall find that we have an apparatus that does to some extent answer the purpose of a level. When we change its inclination, the jelly, but for the sand, would indeed have very little tendency to change its position, but the sand, being specifically heavier than the water, will, and will either move through the jelly, if that is thin enough, or pull the jelly with it. In any case, a change of position of the box will involve a change in the relative position of its contents. In the actual case of the *macula acustica* such a change in the relative position of the sand and the hair cells must give rise to an irritation of the terminations of the nerves, and send a message to the brain. We cannot, as yet, work out all this in detail, as we can the way in which the canals give us information as to the acceleration of rotational motion, but we know enough to turn our attention to the subject; and we may hope that, by more accurate study of the sensation phenomena, and by comparison of them with the anatomical facts, this important and interesting physiological question may be satisfactorily answered.

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